Experimental analysis and investigations on properties of a biological material as lubricant additive

Suresh Babu Koppula^{1,2} · N. V. V. S. Sudheer³

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Abstract

Some conventional fluids such as lubricants, air, water, and others used for cooling of various applications like automobiles, locomotives, machinery, air conditioning and refrigeration, and other industrial applications. However, experimental observations revealed using of conventional fluids is no more advantageous because of advanced additive technologies development in heat transfer areas. Recent technology projected on nano fluids shows, nano materials occupies an important place in changing the properties of various elements in basic structure. Extensive research elaborated that the heat transfer capacity is fully dependent upon thermal conductivity (k) of nano particles, size, diameter and the percentage of volume concentration. Advanced technologies facilitates using nano fluids for improving thermal conductivity in several applications like automobiles, industries, marine and other heat exchangers etc. This Experimental studies focuses on the various properties of lubricants mainly focus on thermal conductivity (k) of Nano fluids for Al_2O_3 , SiO_2 and coal ash. A new biological material used by our ancients as lubricant additive brought up into experimental investigation and results compared with conventional fluids. The particle size is 60 nm measured by electron microscope scanning setup, images taken for the size and characteristics. The experiments carried on by using a pipe in pipe heat exchanger at laminar flow condition by a forced convection mode. These nano fluids prepared at different volume concentrations 0.2%, 0.4%, 0.6% and 1.2% on SAE0W-20 engine oil as base fluid.

Keywords Thermal conductivity · Nano fluids · Al_2O_3 · SiO_2 · Biological material

List of symbols

nm	Nanometers
μm	Micrometre
P	Poise
cP	centiPoise

SEM	Scanning electron microscopy
TEM	Electron microscopy transmission

Abbreviations

ASTM	American Society for Testing and Materials
CFD	Computational fluid dynamics
CNT	Carbon-nano tube
EHL	Elasto hydrodynamic lubrication
EP	Extreme pressure
MWCNT	Multi walled carbon nano tube
SAE	Society of Automotive Engineers

1 Introduction

The major role of the lubricants is to reduce the friction by absorbing the heat and transferring that heat as soon as possible to the surroundings, such that the components protected from overheating, so that efficiency increases as well the life of the components increases. Several investigations did by researchers to minimize or reduce the size and as well cost. Heat exchanger used to transfer of heat energy or internal thermal energy; it is most important device in cooling and heating process such as power

✉ Suresh Babu Koppula, eshsur@gmail.com | N. V. V. S. Sudheer, nvssudheer1969@gmail.com | ¹Department of Mechanical Engineering, Acharya Nagarjuna University, Guntur, AP 522510, India. ²SMEC, Hyderabad, India. ³Department of Mechanical Engineering, RVR & JC College of Engineering, Guntur, AP, 522019, India.

plants, petroleum refineries, transportation industries, air-conditioning, refrigeration, heat recovery elements, cryogenic applications and others. In addition, the concept of heat transfer has important role in metal cutting, lubrication and other manufacturing and production industries. The mean temperature difference logarithmic (LMTD) and heat transfer coefficient overall (OHTC) (U) is used in the analysis and design of heat exchangers as basic parameters. The heat transfer capacity depends on temperature difference in given location for both hot and cold fluids.

Vasisht et al. [1] conducted experiments on Industrial Lubricants and discussed about important rheological parameters which influences on lubricants is viscosity, friction etc., This paper studies on relation between temperature and viscosity for multiple grade and single grade oil lubricants like 1: MC20W-50 (mineral engine oil), 2: MG20W-50 (engine oil), 3: SAE20W-50 (engine oil), 4: DXTIII (steering fluid) and 5: EP90 (gear oil). Frass et al. [2] gave calculation principles to design a heat exchanger with the details of individual problems with special cases. Johnson et al. [3] used lubricant additives as Phosphate, thio phosphate as well as metal thio phosphates. These thio phosphate and phosphate esters used are anti-wear and extreme pressure additives. Hu et al. [4] worked on dialkyl-dithio phosphyl phosphate as lubricant additive with different alkyl groups is tested by a 4-ball tester to analyze the tribological effects on mineral base oil at different loads and results are compared with commercial additives shows excellent anti wear as well load-carrying capacities for better than commercial additives. Choi [5] started experiments on nano fluids by suspending metallic nano particles mixed in water. From observation he found the thermal conductivity nano fluid is more than conventional fluid (base fluid), he analysed the major drawback of suspended particles is that sedimentation of particles leading to increase in pressure drop and friction in the flow channels. Krim et al. [6] worked on Nano fluids thus solid-liquid composites, a mixture of nanoparticles of metallic with different sizes typically of 1–100 nm usually suspended in base fluid.

Vajjha et al. [7–9] did experimentation to determine thermal and physical properties for nano fluids of SiO_2 , Al_2O_3 , ZnO and CuO. Zhmud et al. [10] carried out experiments to study the effects on adding nano additives in lubricants and presented view on various nano additives when mixed lubricating oils. They considered the following types of nano materials nano diamonds, PTFE and ultra-dispersed acid. They discussed advances in nano materials in engine oils, greases and industrial lubricants, concluded addition of nano material greatly influences on lubricating properties. Sundar et al. [11] discussed various enhancements for thermal properties for nano- diamond in nano fluid. Investigators determined various properties

at different temperature ranges and volume fractions. Vajjha et al. [12] evaluated heat transfer coefficients for Reynolds number in turbulent range with CuO , Al_2O_3 and SiO_2 at the temperatures range 20–90 °C with nano particle diameter ranges from 20 to 100 nm and volume concentration 0–10%. Usri et al. [13] studied on 13 nm sized Al_2O_3 particles dispersed into water with three different volume ratios, the data measured gave maximum enhancement on thermal conductivity at concentration 2.0%, temperature of 70 °C. Kavitha et al. [14] concluded on some research work done on synthesis of nano fluids with dilute liquid suspended nano particles and the TiO_2 powder of ~ 6 nm Nano particles are tested by Sol-gel technique. Powders prepared and characterized by using SEM and XRD technique for volume concentrations 1–2%. Ali et al. [15–17] presented enhancement of thermo physical properties such as thermal conductivity and viscosity for engine oil by addition of nano-lubricant in automotive engines. $\text{Al}_2\text{O}_3/\text{TiO}_2$ hybrid nano particles suspended in engine oil (5W-30) with 0.25 wt% concentration and size of 8–12 nm. The results showed that nano-lubricants provide low kinematic viscosity and an increase in the viscosity index by 2%. And thermal conductivity was enhanced by a margin of 12–16% for a temperature range of 10–130 °C. The tests also showed a minimization of the friction coefficient and wear rate of the ring by 40–50% and 20–30%, respectively. According to the results, nano-lubricants can contribute to improving the efficiency of engines and fuel economy in automotive engines viz., brake power, torque, and mechanical efficiency, while the brake specific fuel consumption reduced owing to the mechanical efficiency of the engine improved by 1.7–2.5%, as compared to the engine oil without nanoparticles. In other hand, the graphene nano lubricant improved anti-friction and anti-wear properties by 29–35% and 22–29%, and the exhaust emissions like CO, CO_2 , HC and NO_x were reduced by 2.79–5.42%, as compared to the reference oil. Zawawi et al. [18] did experimentations on thermal conductivity and viscosity of different combination composite nano lubricants at 0.02% and temperatures from 30 to 80 °C. The highest enhancement ratio is 1.010 or 1.035% for $\text{Al}_2\text{O}_3\text{--SiO}_2/\text{PAG}$ composite nano lubricant and the lowest is 1.007 or 0.68% and the maximum dynamic viscosity is 1.098 or 9.79% whereas lowest is 1.012 or 1.19%.

2 Experimental set up and parameters

The major components of experimental set-up is test section which contains horizontal pipe in pipe (copper pipes), cold-water tank, hot lubricating oil tank Rota meters, pumps, sensors. These instruments selected according to the requirement based on measuring range, accuracy and

Fig. 1 Experimental set up

availability in the market. The test section fabricated from copper tubes, which possesses higher thermal conductivity. To achieve any particular engineering problem, we need to follow set of principles for proper product development economically. This economic is important for the design and selection of good heat transfer equipment. The

various heat exchangers fabricated in different types, but the simplest form consists of concentric pipes contains different diameters known as pipe in pipe heat exchanger. In addition, one fluid flows in inner pipe and another fluid flows through annulus space between both the pipes. Out of these fluids, one called hot fluid other called cold fluid. If flow is in same direction called parallel flow and opposite direction called counter flow. The counter flow heat exchanger is much effective than parallel flow for the given surface area, hence considered for present study. For the design purpose, several parametric values assumed to calculate the length and diameter for both pipes. Moreover, various iterations made to optimize these values. The Fig. 1 shows the double pipe heat exchanger experimental set up, on which the experiments were carried out and data collected.

Let

D_i = pipe inner diameter in m; m_{hot} = hot fluid flow rate in LPM; m_{cold} = cold fluid flow rate in LPM; L = length of the inner pipe in m; V_{fluid} = volume of fluid in ml; U = overall

Table 1 Selection of parameters and values

S. no.	Constant parameters				Values	
1					D_i	0.008
2					m_{cold}	2
3					m_{hot}	3
4					U	0.2
5					C_{pc}	4.178
6					C_{ph}	2.219
7					$T_{h,in}$	100
8					$T_{c,in}$	30
9					m_c	0.0333
10					m_h	0.042
11					C_c	0.1393
12					C_h	0.0932
13					C_{min}	0.0932
14					C_{max}	0.1393
15					C	0.6692
16					Q_{max}	6.5239
S. no.	Parameter	1	2	3	4	
1	L	1	1.5	2	2.5	
2	V_{fluid}	50.24	75.36	100.48	125.6	
3	A_s	0.0251	0.0377	0.0502	0.0628	
4	Q_{actual}	0.3365	0.4941	0.6452	0.7902	
5	NTU	0.0539	0.0809	0.1078	0.1348	
6	ε	0.0516	0.0757	0.0989	0.1211	
7	$T_{h,out}$	96.3891	94.6979	93.0768	91.5214	
8	$T_{c,out}$	32.4164	33.5482	34.6331	35.6739	
9	Re	398.0891				
10	h_f	0.0836	0.1254	0.1672	0.209

Fig. 2 Variation of LMTD, Re along the length and diameter

heat transfer coefficient in $\text{kW/m}^2\text{C}$; C_{pc} = specific heat of cold fluid in KJ/kg K ; C_{ph} = specific heat of hot fluid in KJ/kg K ; $T_{h,in}$ = hot fluid inlet temperature in $^{\circ}\text{C}$; $T_{c,in}$ = cold fluid inlet temperature in $^{\circ}\text{C}$; m_c = cold fluid in kg/s ; m_h = hot fluid in kg/s ; A_s = Surface Area in m^2 ; C_c = Heat capacity of cold fluid in kW ; C_h = Heat capacity of hot fluid in kW ; C_{min} = Minimum heat capacity in kW ; C_{max} = Maximum heat capacity in kW ; $C = \text{Capacity Ratio} = C_{min}/C_{max}$; Q_{max} = maximum heat transfer in kW ; Q_{actual} = actual heat transfer in

kW ; NTU = number of transfer units; ϵ = Effectiveness; $T_{h,out}$ = hot fluid outlet temperature in $^{\circ}\text{C}$; $T_{c,out}$ = cold fluid outlet temperature in $^{\circ}\text{C}$; $T_{hi} - T_{ho}$ = hot fluid temperature difference in $^{\circ}\text{C}$; $T_{co} - T_{ci}$ = cold fluid temperature difference in $^{\circ}\text{C}$; LMTD = log mean temperature difference; ρ = density of oil, kg/m^3 ; ν = kinematic viscosity, m^2/s ; Q = discharge, m^3/s ; A_c = cross sectional area, m^2 ; V = velocity, m/s ; Re = reynolds number; f = friction factor; h_f = pressure drop due to friction, bar.

Fig. 3 Variation of h_f , $T_{c,out}$, $T_{h,out}$, NTU and effectiveness along the length

Table 1 represents the selection of various parameters like Specific heat, flow rates, heat capacities etc., and its values.

From the Fig. 2, the smaller diameter of pipe tends to higher LMTD hence greater heat transfer capacity. Whereas larger the diameter of pipe will tends to lower the Reynolds number indicates the flow in the pipe may cause flow obstruction. Hence, from above diagram concluded the preferable diameter is 8 mm or 12 mm and the length 2 m.

From the Fig. 3, at constant diameter of pipe 8 mm as the length increases the pressure drop, heat transfer, NTU, effectiveness increases. The gain in temperature of cold fluid increases, whereas the heat loss of hot fluid decreases.

Conclusion: from above diagrams and discussion even though there is more pressure drop, more temperature difference exists between fluids, it is very important to have flow as high as possible to sustain flow in the pipe. Hence, by compromising other parameters the dimensions of inner pipe is diameter 8 mm and length 2 m.

3 Data collection and calculation of parameters

The various properties of the lubricants measured are as follows:

1. Viscosity (μ)
2. Flash and fire points
3. Specific gravity (SG)
4. Coefficient of friction (C_f)
5. Specific heat (C_p)
6. Heat transfer coefficient (h)
7. Thermal conductivity (k)

Sample calculation for various parameters viz., Viscosity (μ), Flash and fire points, Specific gravity (SG), Coefficient of friction (C_f), Specific heat (C_p), Heat transfer coefficient (h), Thermal conductivity (k) are presented for Al_2O_3 at 0.2% from Tables 2, 3, 4, 5, 6, 7 and 8.

Table 2 represents the estimation of viscosity and density for Al_2O_3 at 0.2% of nano material addition as a sample calculation. The experimental data collected by using redwood viscometer 1. Figure 4 represents comparison of Viscosity and density for Al_2O_3 at different concentrations.

Table 3 and Fig. 5 represent the data collection for flash and fire point for Al_2O_3 at different concentrations and graph shows the comparison of values. The data collected by using Cleveland's flash and fire point apparatus.

Table 4 and Fig. 6 represent the calculation of specific gravity for Al_2O_3 at 0.2% of nano material addition as a

Table 2 Estimation of density and viscosity for 0.2% of Al_2O_3

S. no.	Temperature of oil	Time of collecting 50 ml of oil	Weight of measuring jar	Weight of measuring jar + 50 cc of oil	Mass of oil	Volume of oil	Density of oil	Kinematic viscosity	Dynamic viscosity
Symbol	T	t	W1	W2	m	v	ρ_{oil}	$V \times 10^{-6}$	μ
Units	°C	s	gms	gms	gms	cc	kg/m ³	m ² /s	N s/m ² or Pa s
Relation					[W2-W1]		[m/v]	[At - (B/t)]	[= $\rho \times V$]
1	40	919	17.17	58.75	41.58	50.2	828	226.9223	0.1880
2	60	616	17.17	58.75	41.58	50.8	819	152.0465	0.1245
3	80	293	17.17	58.75	41.58	51.8	803	72.1492	0.0579
4	100	129	17.17	58.75	41.58	52	800	31.3591	0.0251
5	120	76	17.17	58.75	41.58	53.9	771	17.9167	0.0138
6	140	51	17.17	58.75	41.58	54.3	766	9.7385	0.0075

Table 3 Estimation of flash and fire points for Al_2O_3 at different concentrations

S. no.	Material	%	Flash point T	Fire point T
	Symbol			
	Units		°C	°C
1	Al_2O_3	0	200	215
2		0.2	210	220
3		0.4	210	222
4		0.6	215	225
5		0.8	217	223
6		1	220	225
7		1.2	223	227

Table 4 Estimation of specific gravity for Al_2O_3 at different concentrations

S. no.	Tempera- ture of oil	Density of oil	Density of water	Specific gravity
	Symbol T	ρ_{oil}	ρ_w	SG
	Units °C	kg/m ³	kg/m ³	
	Relation	ρ_{oil}/ρ_w		
1	40	828	1000	0.8283
2	60	819	1000	0.8185
3	80	803	1000	0.8027
4	100	800	1000	0.7996
5	120	771	1000	0.7714
6	140	766	1000	0.7657

sample calculation and comparison of specific gravity for Al_2O_3 at different concentrations.

Tables 5 and 6 represents the estimation of Friction and Specific heat for Al_2O_3 at 0.2% of nano material addition as a sample calculation. Figure 7 represents comparison for Friction and Specific heat for Al_2O_3 at different concentrations.

Tables 7 and 8 represents the calculation of HTC and thermal conductivity for Al_2O_3 at 0.2% of nano material addition as a sample calculation. Figure 8 represents comparison of HTC and thermal conductivity for Al_2O_3 at different concentrations.

Figure 9 shows the photo graph taken while measuring the size of nano particles by using SEM technology

4 Results and discussion

From the above data, the following results obtained and compared for nano fluids at 0.2%, 0.4%, 0.6% and 1.2% for Al_2O_3 , SiO_2 , Coal Ash and Biological material:

Table 5 Estimation of friction coefficient for 0.2% of Al_2O_3

S. no.	Temperature of oil T	Manometer reading h	Density of mercury ρ_{mer}	Pressure drop ΔP	Volume flow of oil Q_{oil}	Velocity of oil V_{oil}	Density of oil ρ_{oil}	Darcy friction factor f	Friction coefficient C_f
	Symbol Units Relation								
1	40	0.0221	13,500	2926.8135	0.0000025	0.0498	828.2869	11.4208	2.8552
2	60	0.0204	13,500	2701.6740	0.0000025	0.0498	818.5039	10.6683	2.6671
3	80	0.0185	13,500	2450.0475	0.0000025	0.0498	802.7027	9.8651	2.4663
4	100	0.0160	13,500	2118.9600	0.0000025	0.0498	799.6154	8.5649	2.1412
5	120	0.0132	13,500	1748.1420	0.0000025	0.0498	771.4286	7.3242	1.8311
6	140	0.0111	13,500	1470.0285	0.0000025	0.0498	765.7459	6.2047	1.5512

Table 6 Estimation of specific heat for 0.2% of Al_2O_3

S. no.	Tempera- ture of oil	Hot fluid inlet temp	Hot fluid outlet temp	Cold fluid inlet temperature	Cold fluid outlet temperature	Hot fluid flow rate	Cold fluid flow rate	Specific heat of water	Heat transfer rate	Specific heat of oil
Symbol	T	T_{hi}	T_{ho}	T_{ci}	T_{co}	m_h	m_c	C_{pw}	Q	$C_{p oil}$
Units	°C	°C	°C	°C	°C	kg/s	kg/s	J/kg K	W	J/kg K
Relation									$m_c * C_{pw} * (T_{co} - T_{ci})$	$Q / (m_h * (T_{hi} - T_{ho}))$
1	40	38.9	33.5	32.9	34.2	0.0021	0.0042	4178	22.63	2023.8858
2	60	58.7	36.2	33.1	38.5	0.0020	0.0042	4178	94.01	2041.7739
3	80	76.4	40.5	33.3	41.9	0.0020	0.0042	4178	149.71	2078.1001
4	100	95.6	49.6	33.9	44.9	0.0020	0.0042	4178	191.49	2082.4323
5	120	114.5	55.2	35.1	48.8	0.0019	0.0042	4178	238.49	2085.3903
6	140	134.3	63.4	34.8	51.1	0.0019	0.0042	4178	283.76	2090.6142

Table 7 Estimation of heat transfer coefficient for 0.2% of Al_2O_3

S. no.	Tempera- ture of oil	Hot fluid inlet temp	Hot fluid outlet temp	Cold fluid inlet tempera- ture	Cold fluid out- let tempera- ture	Temp diff between hot fluid inlet and hot fluid outlet	Temp diff between cold fluid inlet and cold fluid outlet	Heat transfer rate	Convective heat transfer coefficient
Symbol	T	T_{hi}	T_{ho}	T_{ci}	T_{co}	ΔT_h	ΔT_c	Q	h_i
Units	°C	°C	°C	°C	°C	°C	°C	W	W/m ² K
Relation						$T_{hi} - T_{ho}$	$T_{co} - T_{ci}$	$m_c * C_{pw} * (T_{ci} - T_{co})$	$Q / (\Delta T_h * A_i)$
1	40	38.9	33.5	32.9	34.2	5.4	1.3	22.6308	83.4175
2	60	58.7	36.2	33.1	38.5	22.5	5.4	94.0050	83.1608
3	80	76.4	40.5	33.3	41.9	35.9	8.6	149.7117	83.0064
4	100	95.6	49.6	33.9	44.9	46	11	191.4917	82.8595
5	120	114.5	55.2	35.1	48.8	59.3	13.7	238.4942	80.0522
6	140	134.3	63.4	34.8	51.1	70.9	16.3	283.7558	79.6616

Table 8 Estimation of thermal conductivity for 0.2% of Al₂O₃

S. no.	Temperature of oil	Nusselt number	Heat transfer coefficient	Thermal conductivity of fluid
Symbol	T	Nu	h _i	k _{nf}
Units	°C		W/m ² K	W/mK
Relation		Constant heat flux		(h _i * d)/Nu
1	40	4.36	83.4175	0.1531
2	60	4.36	83.1608	0.1526
3	80	4.36	83.0064	0.1523
4	100	4.36	82.8595	0.1520
5	120	4.36	80.0522	0.1469
6	140	4.36	79.6616	0.1462

Fig. 4 Density and viscosity for Al₂O₃ at different concentrations

Fig. 5 Flash and Fire points for Al₂O₃ at different concentrations

1. Comparison of viscosity

From the Fig. 10, it is clear that the decreasing order of viscosity is coal ash, SiO₂, Al₂O₃ and Biological material at any given temperature ranges from 40 to 140 °C. As the concentrations 0.2%, 0.4%, 0.6% and 1.2% are increasing the viscosity also increases. Hence, from the viscosity point of view the addition of Biological material is preferable than others. Because, the increase in viscosity decreases Reynolds number (by keeping the other parameters constant) causes the difficulty in flow of the fluid, it also increases the friction.

2. Comparison of flash and fire points

From the Fig. 11, it is understand that the reduction of flash and fire points is Al₂O₃, SiO₂, coal ash and Biological

Fig. 6 Specific gravity for Al_2O_3 at different concentrations **Fig. 7** Friction and Specific heat for Al_2O_3 at different concentrations **Fig. 8** HTC and thermal conductivity for Al_2O_3 at different concentrations

Fig. 9 SEM photo graph to measure size

material at any given temperature ranges from 40 to 140 °C. As the concentrations 0.2%, 0.4%, 0.6% and 1.2% increases the flash and fire points are increasing. Hence, from the flash and fire points of view the addition of Al_2O_3 is preferable than others. Because, the increase in flash and fire points is reliable for the lubricants and increases the operating temperatures of fluids.

3. Comparison of friction

From the Fig. 12, it is clear that the decreasing order of Friction is coal ash, SiO_2 , Al_2O_3 and Biological material at

any given temperature ranges from 40 to 140 °C. As the concentrations 0.2%, 0.4%, 0.6% and 1.2% are increasing the Friction also increases. Hence, from the Friction point addition of Biological material is preferable than others. The increase in Friction effects on pipe material like etching, scratching.

4. Comparison of heat transfer coefficients

From the Fig. 13, the average values at any temperature ranges from 40 to 140 °C at the concentrations 0.2%, 0.4%, 0.6% and 1.2% is given in Table 9.

Fig. 10 Comparison of viscosity at 0.2%, 0.4%, 0.6% and 1.2% concentrations

Fig. 11 Comparison of flash and fire points at 0.2%, 0.4%, 0.6% and 1.2% concentrations

It is clear that the decreasing order of HTC Al_2O_3 , Biological material, SiO_2 and coal ash at any given temperature ranges from 40 °C to 140 °C. As the concentrations 0.2%, 0.4%, 0.6% and 1.2% are increasing the HTC for Biological material is greatly increases compared to others. Hence, from the HTC point of view the addition of Biological material is preferable than others. The increase in HTC increases heat transfer capacity and thermal conductivity.

5. Comparison of thermal conductivity

From the Fig. 14, the average values at any temperature ranges from 40 to 140 °C at the concentrations 0.2%, 0.4%, 0.6% and 1.2% is given in Table 10.

It is clear that the decreasing order of Thermal Conductivity Al_2O_3 , Biological material, SiO_2 and coal ash at any given temperature ranges from 40 to 140 °C. As the

Fig. 12 Comparison of friction at 0.2%, 0.4%, 0.6% and 1.2% concentrations

Fig. 13 Comparison of heat transfer coefficient at 0.2%, 0.4%, 0.6% and 1.2% concentrations

Table 9 Average values of HTC at concentrations 0.2%, 0.4%, 0.6% and 1.2%

	Al ₂ O ₃	SiO ₂	Coal ash	Biological
0.2%	82.0263	80.0582	79.3362	81.328
0.4%	82.1458	79.7425	79.0224	81.6787
0.6%	83.4986	80.5683	79.9277	83.5526
1.2%	85.6474	83.6531	83.0642	88.9275

Table 10 Average values of Thermal Conductivity at concentrations 0.2%, 0.4%, 0.6% and 1.2%

	Al ₂ O ₃	SiO ₂	Coal ash	Biological
0.2%	0.1505	0.1469	0.1456	0.1492
0.4%	0.1507	0.1463	0.145	0.1499
0.6%	0.1532	0.1478	0.1467	0.1533
1.2%	0.1572	0.1535	0.1524	0.1632

concentrations 0.2%, 0.4%, 0.6% and 1.2% are increasing the Thermal Conductivity for Biological material is greatly increases compared to others. Hence, from the Thermal Conductivity point of view the addition of Biological material is preferable than others. The increase in Thermal Conductivity increases heat transfer capacity as well as performance of lubrication for the fluids.

5 Conclusion

The contribution of this analysis is to review research on current state in lubricating properties for lubricants in various applications with special reference to addition of nano particles focused on use of Al₂O₃, SiO₂, coal ash and making comparison of results obtained with Biological material for various properties for improvement of life of the machines. Results show that biological material having a very good characteristics and excellent potential with an excellent thermal conductivity with low friction compared to others. Hence, the addition of nano materials for lubricants increases thermal conductivity as well as

Fig. 14 Comparison of thermal Conductivity at 0.2%, 0.4%, 0.6% and 1.2% concentrations

heat transfer rate about 6–11% by Al_2O_3 , 1–10% by SiO_2 , 2–9% by Coal ash and 5–18% by Biological Material. The scope of future work expected is unlimited in this area. More research works can be carried out towards further implementation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Data availability The raw/processed data required to reproduce these findings cannot be shared at this time due to legal or ethical reasons.

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