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# EFFECT OF HEATING INTERVAL AND CONTAMINATION WITH WATER ON STEAM TURBINE LUBRICANT VISCOSITY

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**ABSTRACT:-** Several factors affect lubricant viscosity that make its value undesirable and out of the working range. This study includes the effect of two factors, heating interval and contamination with water, on kinematic viscosity at atmospheric pressure for steam turbine lubricating oil. The experimental program take into account increasing the temperature of the lubricant oil (ISO32) by heating to specified temperature and time interval. Also the lubricant has been contaminated with a particular water contents. The values of these factors are chosen to represent the inspected real working conditions of steam turbine lubricant at south Baghdad thermal power plant. Experimental heating intervals are (20, 40, 60, 80 and 100) hours. Heating temperature is (60)°C. Water contamination of oil expressed as a percentage are 0.3%, 0.6%, 0.9%, 1.2% and 1.5%.

The results show that oil kinematic viscosity decreases as heating interval increased by (4.7, 12, 19.6, 27.1, 34.2)%. Also the oil kinematic viscosity decreases as contamination with water increases by (1.1, 2.3, 3.6, 4.9, 6.9) % respectively and as an average for the above heating intervals. The decrease in kinematic viscosity due to heating approximately reaches unrecommended level at 40 hours as experimental heating interval, while the decrease in kinematic viscosity of oil due to contamination with water reaches unrecommended level when water content in oil exceeds 1.5%.

***Keywords:*** Lubricant Contamination, Viscosity, Steam turbine Lubrication.

## INTRODUCTION NOTATIONS

Lubrication plays a most vital role in our great and complex civilization. Every machine is subjected to friction and wear. Friction consumes and wastes about one third to one half of the total energy produced in the world. Wear causes changes in element's dimensions and entire machine breakdown and that's led most people to search on reducing and controlling friction and wear through the use of lubricant (1).

For any power generation facility, any problem requiring an unexpected shutdown of the main turbine is likely to cause a significant unplanned outage, resulting in high downtime costs. According to a 1991 study by General Electric Company/ USA, turbines contribute on average 20 percent of all forced outages in a conventional power plant. Among this 20 percent, General Electric Company noted that 19 percent of turbine and generator problems were associated with the lubrication oil system. For this reason, monitoring turbine oils has become commonplace in the power generation industry (2).

The factors that affect Lubricants include:

## HEAT AND THERMAL EFFECTS

### • Contamination

- Water contamination.
- Particles and wear debris contamination.
- Soot and unburned fuel in an engine.
- Dust from atmosphere.
- Microbial or bacterial contamination.

### • Oxidation.

Thermal degradation takes place when the oil comes in contact with hot surfaces or spots inside the machine such as bearing surfaces and combustion or exhaust areas. This can cause lubricant to vaporize or decompose, certain additives to be removed from it and lubricant viscosity may increase, especially when it is heated above its stable recommended temperature which is below 75°C for steam turbine oil. Thermal failures result in hydrocarbons chain cracks into smaller subsets of itself causing the viscosity to decrease. This thermal cracking is often referred to as thermal breakdown (3, 4).

Also heat can initiate and increase suddenly and rapidly with adiabatic compression of entrained air bubbles in pumps, bearings and other pressurized lubrication environments which affects the layer of oil that comes in contact with it (5).

The viscosity of water is lower than virtually any lubricant, and its viscosity does not increase with increasing pressure as lubricants do. Water adversely affects bearing condition by causing insufficient fluid film strength and allowing bearing surfaces to come into contact.

The resulting emulsion will have a viscosity higher than water but lower than the oil, and proper oil film thickness will not be achieved (6).

Sources of water contamination are:

- Shaft seal leaks in steam turbines.
- Heat exchanger or oil cooler leaks.
- Condensation of humid air in reservoir and other system areas.
- Inadequate reservoir covers.

Water content in oil is usually measured in percents of volume (%) or in parts per million (ppm) (7 , 8).

Osama M.J 2006 (9) presented a research about lubricant degradation due to heating and contamination with fuel soot in internal combustion engine. In the first part of this case, 6 liters of crank case oil where allowed to heat up for three different temperatures ( 60°C, 90°C, 120°C ) and for an interval of 12 hours. A sample of oil was drawn after every one hour. In the second part of this case the same above parameters and procedure were used but in addition mixing of exhaust gases of the engine was used with the 6 liters of heated oil.

The main results of the first part were:

Viscosity of crank case oil decreased with increasing heating time to 12 hours by 5% at 60°C, 12% at 90°C and 30% at 120°C.

The main results of the second part were:

Viscosity of crank case oil increased with increasing heating time to 12 hours by 5% at 60°C, 9% at 90°C and 15% at 120°C.

Greely, J. 2006 (10) presented a research about compressor oils contamination. The study was focused on rotary screw type compressor oils. The high speed rotors in rotary screw air compressors compress large volumes of air, at the same time oil is injected to the rotor to lubricate the moving parts during compression. When air or process gases are compressed, moisture from humidity condenses and is collected in the oil, creating the need for the oil to have good hydrolytic stability, which is important to help in preventing oil degradation from hydrolysis, which forms acids and contributes to foaming. Water contamination in rotary screw compressors can be developed from large amounts of ingested air containing small amounts of moisture. This moisture can build up and cause water-oil emulsions causing shortened oil drain interval. The oil in rotary screw compressor experience severe air and oil churning therefore foaming of the oil is likely to occur. The results of a certain test for different types of compressor oils show the percentage change in viscosity for the lubricants

(Mobil, Amsoil, royal 46, Anderal and keaser) were (-0.16, -0.45, -0.98, 0.18 and 4.83)% respectively.

## STEAM TURBINE LUBRICANT

The oil used to lubricate the couple of combined journal and thrust bearings of steam turbine, is of type ISO32 grade with specific gravity of 0.87 at 15.6°C, viscosity index of 95, pour point of -15°C and flash point of 200°C. At the beginning 30 liters of new turbine oil was obtained from the south Baghdad thermal power plant, so as to cover the need of new turbine oil required to perform all the experimental work.

## EQUIPMENT SETUP

- Measurement of water content in oil was achieved using centrifuge apparatus (available at lubricant laboratory/ midland refineries company / daura refinery)
- Viscosity measurements were achieved using glass viscometer measuring apparatus along range of temperatures from 30°C to 100°C. (available at lubricant laboratory/ chemical engineering department/ university of Technology). Three sizes of viscometer were used to provide measuring range from 2 to 100 cSt.
- To simulate the effect of heating intervals and water content on viscosity of turbine oil, it was necessary to assemble an equipment to impose these effects on turbine oil and produce samples affected by specified heating intervals and water contamination levels, as shown in Fig.(1). This equipment consists of the following parts:
  1. Heating and mixing unit.
  2. Steam generator unit.

**Heating and mixing unit :** consists of Five glass container with a side lower opening 1/2 inch in diameter to discharge the oil to the oil pump. The container is opened from the top and is provided with circular steel cover containing holes. One of them is connected to a 1/2 inch steel pipe represents an oil intake which is connected to the heating pipe through a rubber heat resistant pipe, while the lower opening is connected through a similar rubber pipe to the oil pump.

**Oil pump:** an electrical pump to circulate the oil through the parts of the equipment.

Heating pipe: a vertical steel pipe 1.5 inch in diameter contains 1000 watt internal heater coil which is fastened to it from top. This heating pipe is connected from the lower end to the oil pump through 1.5/1 inch adapter and from the top to the upper rubber pipe through a lateral

1/2 inch horizontal pipe with 1.5/0.5 inch adapter. The oil flow direction is from bottom to top.

**Thermal electrical controller:** this controlling unit measures oil temperature through a thermocouple type (k) fastened to the heater's head, and displays the readings. Also the controller provides power to the heater through a contactor and wires connected to heater's head. Oil temperature is maintained at certain value by setting it on the controller keypad.

**Steam Generator Unit:** it is a seven liters cylindrical steel container with three openings from top. One for refilling with water when it is needed, the second as safety valve and the third as discharge valve, which provides a certain steam flow rate and it is connected with (0.24) inch diameter copper isolated pipe which passes through the cover of the mixing container to dive into the oil. This steam generator rests on a single propane burner which is connected to a traditional propane bottle. This burner represents an efficient flexible heat source for a steady boiling process for water.

## EXPERIMENTAL PROCEDURE

- Filling the glass container of heating and mixing unit with 4 s of new turbine oil.
- Starting oil pump to circulate the oil through the unit.
- Maintaining oil temperature at 60°C by setting the controller on this value.
- Allowing the oil to be heated at this temperature for the required heating interval.
- After the required heating interval ends, steam generator should be operated and connected to the steam pipe which dives into oil, for a limited time that is sufficient to produce the required percentage of water in oil.
- An oil sample of 100 ml is taken from the heating and mixing glass container. 50 ml is for checking percentage of water in oil and the rest is for viscosity measurement.
- After shutting down all the operating parts of the equipment, the residual oil is discharged and heating and mixing glass container is cleaned for the next 4 liters of new oil to produce the next six samples. Table (1) represents samples sequence according to drawing priority.

## RESULTS AND DISCUSSION

Referring to the results presented in figures (2 to 7) the following observations can be made:

- The viscosity of turbine oil decreases as heating interval increased.

- For result of particular water content in oil, the curves are approximately similar to each other and they tend towards convergence as measuring temperature increases. Also they are divergent as measuring temperature decreases. This may be noted by comparing the difference in viscosity values of the initial and final heating interval at (30 and 100) °C.
- The viscosity of oil is inversely proportional with water content. This can be noted by moving from any diagram to the next of figures (2 to 7).
- All viscosity-temperature curves follow a slight irregular path at 50°C, the reason for that is attributed to the change in viscometer size at this temperature and the difference in viscometer accuracy associated with this change.
- The drop in oil viscosity due to heating intervals increases as sample temperature increases and the average drop ratio in oil viscosity increases as heating interval increases as shown in table (2).
- The drop in oil viscosity due to water contamination increases as sample temperature increased.
- The average drop ratio in oil viscosity increases as water content in oil increases, also as temperature increases up to 80°C after that it decreases. This shows the decreasing effect of water contamination on oil viscosity at 90°C and 100°C due to evaporation of water content, as shown in table (3).
- It was observed that more decrease in kinematic viscosity of steam turbine oil cause sensible vibration of turbine rotor due to the decrease in oil film thickness and the contact between bearing surfaces which result in turbine damages.

## CONCLUSIONS

- Kinematic viscosity of turbine oil decreases as heating interval increases and the decrease in kinematic viscosity due to heating only at 60°C for (20, 40, 60, 80, 100) hours is (4.7%, 12%, 19.6%, 27.1%, 34.2%) respectively. But with existence of contamination with water the average decrease in viscosity due to heating and for the same experimental heating interval is (5.2%, 12.4%, 20.6%, 28%, 35.4%) respectively.
- Kinematic viscosity of turbine oil decreases as water content in oil increases and the decrease in kinematic viscosity due to contamination with water only at 60°C for (0.3%, 0.6%, 0.9%, 1.2%, 1.5%) water content in oil is (1.1%, 2.3%, 3.6%, 4.9% , 6.9%) respectively. But with association of heating at 60°C the average decrease in kinematic

viscosity due to contamination with water and for the same water contents in oil is (1.5%, 2.9%, 4.5%, 6.2%, 8.4%) respectively.

- A working alarm range is +20% over nominal viscosity value and -10% under nominal viscosity value. Now for the conclusion of 1st point the decrease in kinematic viscosity due to heating approximately reaches unrecommended level at 40 hours as experimental heating interval. For conclusion of 2nd point the decrease in kinematic viscosity of oil due to contamination with water reaches unrecommended level when water content in oil exceeds 1.5%.
- The results indicate that the effect of heating interval on kinematic viscosity is greater than the effect of contamination with water within the range of both factors that were studied.

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**Fig.(1):** The Assembled Equipment.

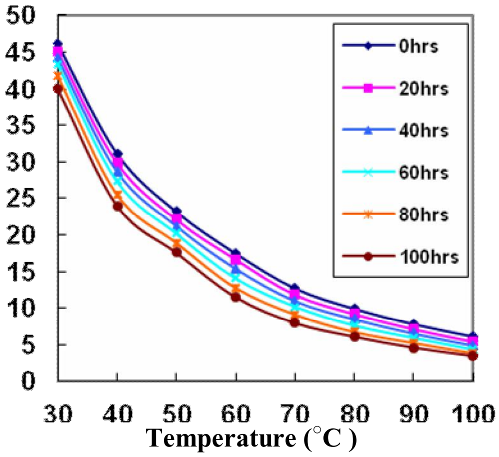

**Fig. (2):** Heating only 0% Water Content

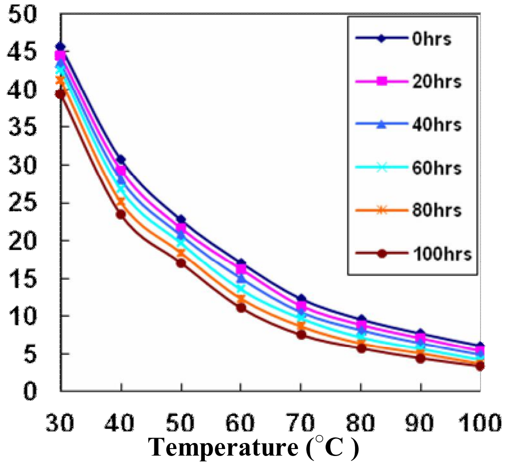

**Fig. (3):** Heating with 0.3% Water Content.

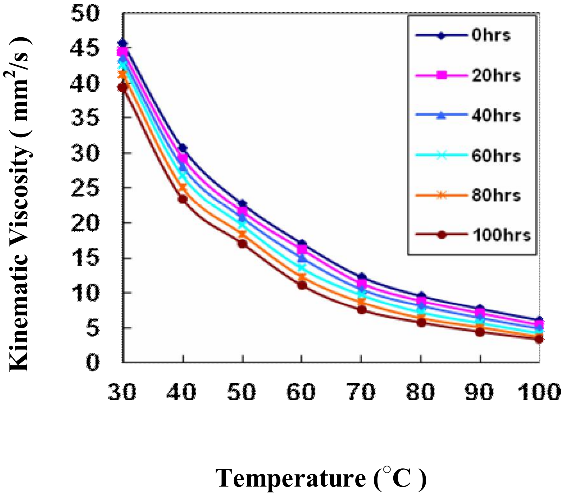

**Fig.(4):** Heating with 0.6% Water Content.

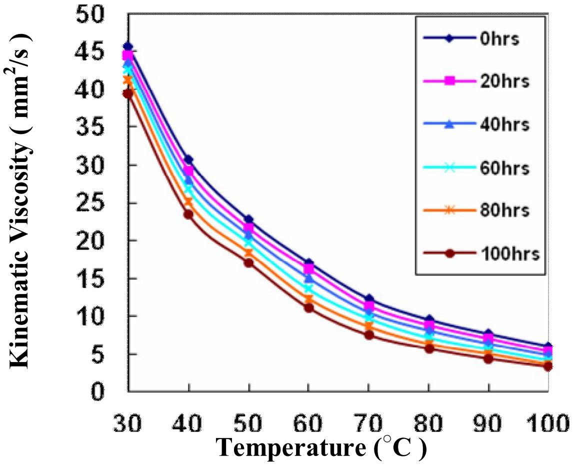

**Fig. (5):** Heating with 0.9% Water Content.

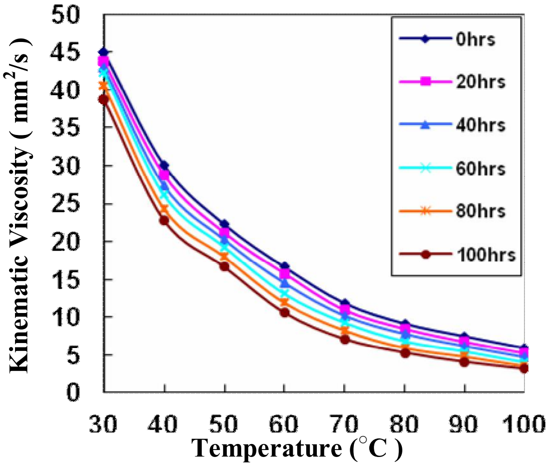

**Fig. (6):** Heating with 1.2% Water Content.

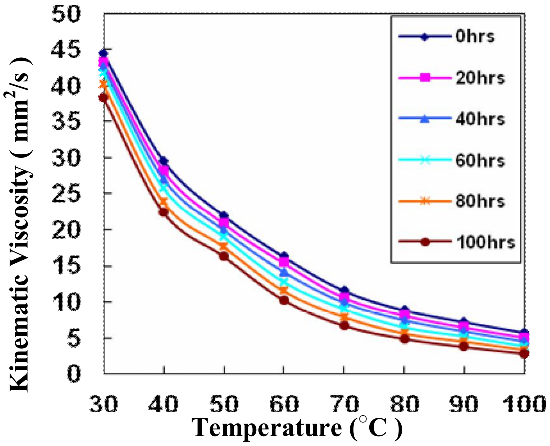

**Fig. (7):** Heating with 1.5% Water Content.

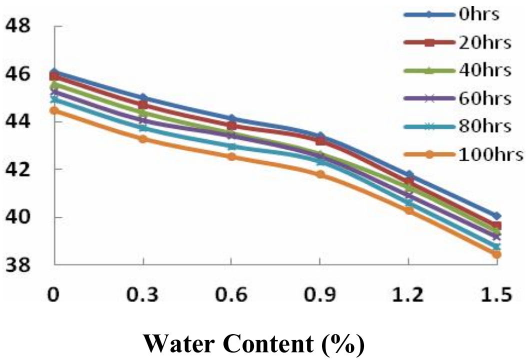

**Fig. (8):** at 30°C.

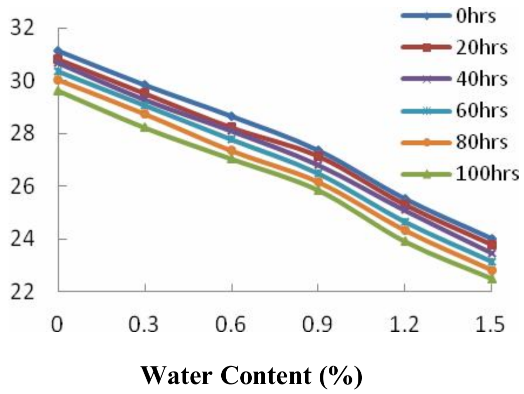

**Fig. (9):** at 40°C .

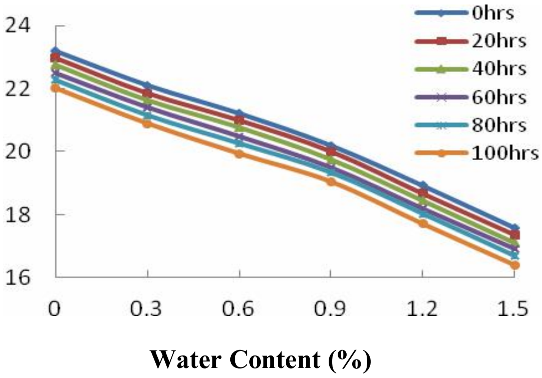

**Fig.(10):** at 50°C .

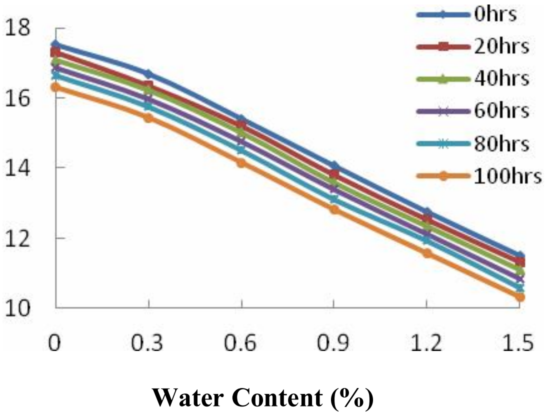

**Fig. (11):** at 60°C.

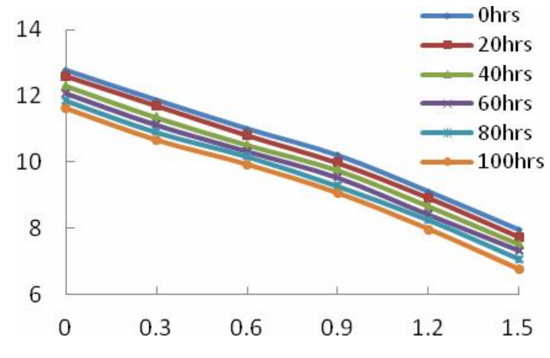

**Fig.(12):** at 70°C .

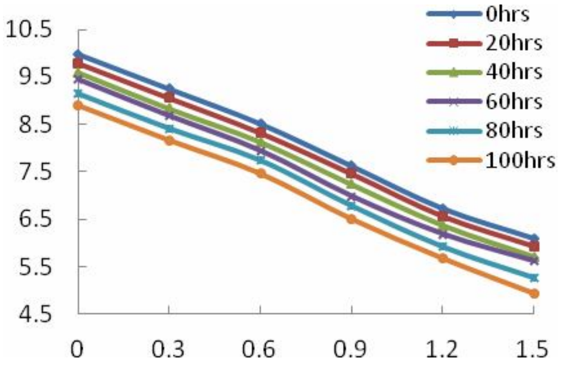

**Fig. (13):** at 80°C .

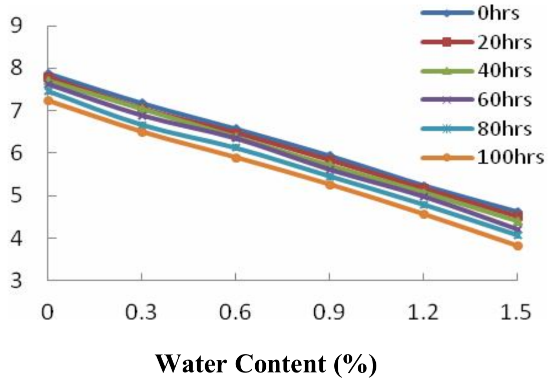

**Fig. (14):** at 90°C.

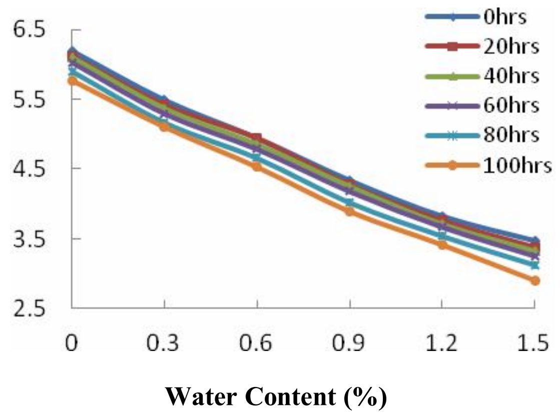

**Fig.(15):** at 100°C .

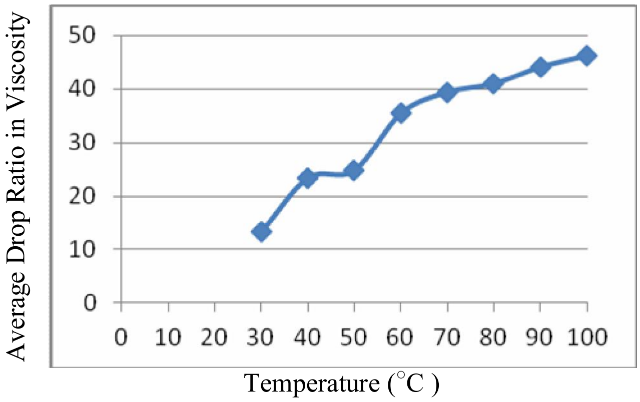

**Fig. (16):** Average Drop Ratio in Viscosity at 100 hours.

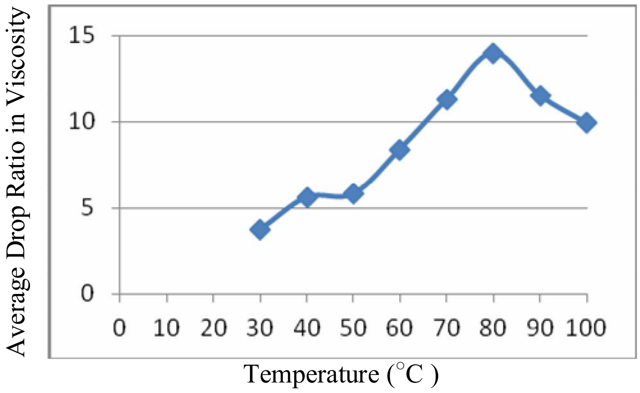

**Fig.(17):** Average Drop Ratio in Viscosity at 1.5%.

**Table (1):** oil samples sequence.

| | | Heating Intervals [hrs] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 20 | 40 | 60 | 80 | 100 |
| Water Contents | 0% | 0 | 6 | 12 | 18 | 24 | 30 |
| | 0.3% | 1 | 7 | 13 | 19 | 25 | 31 |
| | 0.6% | 2 | 8 | 14 | 20 | 26 | 32 |
| | 0.9% | 3 | 9 | 15 | 21 | 27 | 33 |
| | 1.2% | 4 | 10 | 16 | 22 | 28 | 34 |
| | 1.5% | 5 | 11 | 17 | 23 | 29 | 35 |

**Note:** 0 hrs represent new oil samples that are not affected by heating.

**Table (2):** average drop in viscosity for all heating intervals.

| | Average Drop Ratio in Viscosity at 1.5% Water Content | | | | |
|---|---|---|---|---|---|
| Temp. °C | 20 hrs | 40 hrs | 60 hrs | 80 hrs | 100 hrs |
| 30 | 2.5 | 4.3 | 5.9 | 9.4 | 13.4 |
| 40 | 4.3 | 8.4 | 12.5 | 18.5 | 23.4 |
| 50 | 4.8 | 8.8 | 13.1 | 18.9 | 24.8 |
| 60 | 5.2 | 12.4 | 20.6 | 28 | 35.4 |
| 70 | 7.6 | 14.2 | 21 | 29.8 | 39.3 |
| 80 | 7.8 | 15.3 | 25.1 | 34.1 | 40.9 |
| 90 | 9.5 | 17.3 | 26 | 34.8 | 44 |
| 100 | 11.8 | 20.5 | 30.9 | 39.3 | 46.1 |

**Table (3):** average drop in viscosity for all water contents.

| | Average Drop Ratio in Viscosity at 100 hrs | | | | |
|---|---|---|---|---|---|
| Temp. °C | 0.3 % | 0.6 % | 0.9 % | 1.2 % | 1.5 % |
| 30 | 0.7 | 1.4 | 1.9 | 2.7 | 3.7 |
| 40 | 1 | 1.8 | 3 | 4.2 | 5.6 |
| 50 | 1.1 | 2.2 | 3.4 | 4.4 | 5.8 |
| 60 | 1.5 | 2.9 | 4.5 | 6.2 | 8.4 |
| 70 | 1.9 | 4.5 | 6.6 | 8.7 | 11.3 |
| 80 | 2.2 | 4.8 | 7.1 | 10.4 | 14 |
| 90 | 1.5 | 3 | 4.9 | 7.9 | 11.5 |
| 100 | 1.3 | 2.6 | 3.9 | 6.8 | 9.9 |

# تأثير فترة التسخين والتلوث بالماء على لزوجة المزيت المستخدم في التوربين البخاري

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## الخلاصة

تتأثر لزوجة المزيتات بعدة عوامل والتي تجعل قيمتها تبتعد عن المدى التشغيلي المسموح . يتناول هذا البحث دراسة أثنين من هذه العوامل وهما زمن التسخين و التلوث بالماء وتأثيرهما على اللزوجة الكينماتيكية عند الضغط الجوي لزيت تزييت التوربين البخاري. الجانب العملي اخذ بنظر الأعتبار تسخين وتلويث زيت التوربين (ISO32) لدرجة حرارة معلومة وزمن معلوم. تم أختيار القيم التجريبية لهذين العاملين المؤثرين بالأستناد على الفحوصات المنجزة على زيت التوربين خلال فترة عمله والمعلومات التي تم الحصول عليها. أن فترات التسخين التجريبية كانت (٢٠ ، ٤٠ ، ٦٠ ، ٨٠ ، ١٠٠ ) ساعة ، كانت درجة حرارة التسخين ٦٠ درجة مئوية أما نسبة تلوث الزيت بالماء فقد تم تمثيلها بنسب مئوية وهي ٠.٣% ، ٠.٦% ، ٠.٩% ، ١.٢% ، ١.٥ % .

أظهرت النتائج بأن اللزوجة الكينماتيكية للزيت تنخفض كلما زادت فترة التسخين. وكذلك تنخفض اللزوجة الكينماتيكية للزيت بزيادة المحتوى المائي.

إن النقصان في اللزوجة الكينماتيكية للعينات بسبب التسخين يصل الى الحد الأدنى المسموح عند ٤٠ ساعة تقريباً كفترة تسخين تجريبية ، أما النقصان بسبب الأستحلاب بالماء فأنه يصل الى الحد الأدنى المسموح عندما يتجاوز المحتوى المائي في الزيت نسبة ١.٥ % تقريباً .

**الكلمات الدالة:** تلوث المزيت، اللزوجة، تزييت التوربين البخاري.