

CONTENTS

| | |
|-------------------------|-----|
| Dedication..... | i |
| Acknowledgement..... | ii |
| Contents..... | iii |
| List of tables..... | Vi |
| List of figures..... | Vii |
| Abstract (English)..... | x |
| Abstract (Arabic)..... | xi |

Chapter one Introduction

| | |
|---|---|
| 1.1 Introduction..... | 1 |
| 1.2 Composition of lubricant..... | 2 |
| 1.2.1 Normal paraffins..... | 2 |
| 1.2.2 Iso-paraffins (branched paraffins)..... | 3 |
| 1.2.3 Cycloparaffins..... | 4 |
| 1.2.4 Aromatic hydrocarbons..... | 4 |
| 1.2.5 Olefins..... | 5 |
| 1.2.6 Elements..... | 6 |
| 1.2.7 Chemical additives..... | 8 |
| 1.2.7.1 Viscosity index improve..... | 8 |
| 1.2.7.2 Additives to lower pour point..... | 8 |
| 1.2.7.3 Anti oxidants..... | 8 |
| 1.2.7.4 Detergent and dispersant additives..... | 9 |
| 1.2.7.5 Anti-foaming agents..... | 9 |
| 1.2.7.6 Rust and corrosion inhibitors..... | 9 |
| 1.2.7.7 Anti-wear..... | 9 |

| | |
|---|------------|
| Used Lubricating oils..... | 10 1.3 |
| Viscosity of the used Lubricant..... | 11 1.3.1 |
| Acid number of the used Lubricant..... | 11 1.3.2 |
| Base number of the used Lubricant..... | 12 1.3.3 |
| Flash point of the used Lubricant..... | 12 1.3.4 |
| Used Lubricating oil recycling processes..... | 12 4.1 |
| The acid processes..... | 13 4.1 .1 |
| The phenol treating | 14 4.2 .1 |
| Furfural treating | 15 4.3 .1 |
| The Institut Francais du P'etrole (IFP) type processes..... | 16 4.4 .1 |
| The KTI type processes..... | 16 4.5 .1 |
| The MOHAWK process..... | 17 4.6 .1 |
| The Phillips Re-refined Oil Process (PROP)..... | 17 4.7 .1 |
| The BETC process..... | 18 4.8 .1 |
| The UOP DCH process..... | 19 4.9 .1 |
| The Texaco Gasification Process..... | 19 4.10 .1 |

Chapter two lubricant properties

| | |
|----------------------------|----------|
| Lubricant properties..... | 20 .2 |
| Kinematic viscosity..... | 20 2.1 |
| Viscosity index..... | 20 .2.2 |
| Flash point..... | 21 .3 .2 |
| Fire point..... | 21 .4 .2 |
| Acidity and Basicity..... | 22 .2.5 |
| Color..... | 22 .6 .2 |
| Density..... | 22 .7 .2 |
| Pour point..... | 23 .8 .2 |
| Infrared spectrometry..... | 23 .9 .2 |

| | |
|---|-------------|
| Ultra violet spectrometry..... | 26 .10 .2 |
| Metalic ash determination..... | 26 .11 .2 |
| Oil efficiency..... | 26 .12 .2 |
| American Society for Testing and Materials (ASTM)..... | 27 1 .12 .2 |
| Chapter three experimental work | |
| Acid treatment..... | 31 3.1 |
| Viscosity test | 40 .3.2 |
| Flash point test | 41 .3.3 |
| Total Acid Number (T.A.N)test..... | 42 .3.4 |
| Total Base Number(T.B.N) test..... | 43.3.5 |
| Density test..... | 44 .3.6 |
| Determination of Zn and Ca | 45 .3.7 |
| Determination of ash, Nikel, and Chromium content..... | 46 .3.8 |
| IR test..... | 47 .3.9 |
| Chapter four results..... 48 | |
| Chapter five discussion & conclusion..... 68 | |
| Chapter six references..... 78 | |

LIST OF TABLES

Page No

| | |
|---|----|
| TABLE 1: Main contaminant elements and their probable origin..... | 7 |
| TABLE 2: Infrared spectrometry some functional groups in lubricants.. | 24 |
| TABLE 3: Gasoline engines..... | 28 |
| TABLE 4: Diesel engines..... | 29 |
| TABLE 5: Viscosity at 100 °C/cSt..... | 48 |
| TABLE 6: Viscosity at 40 °C/cSt..... | 49 |
| TABLE 7: Flash point °C..... | 50 |
| TABLE 8: Total Acid Number (T.A.N) mg KOH/g..... | 51 |
| TABLE 9: Total Base Number (T.B.N) mg KOH/g..... | 52 |
| TABLE 10: Density at 15 °C..... | 53 |
| TABLE 11: Zn PPm..... | 54 |
| TABLE 12: Ca PPm..... | 55 |
| TABLE 13: Ash content (g%)..... | 56 |
| TABLE 14: Ni content ($\mu\text{g}/\text{ml}$)..... | 57 |
| TABLE 15: Cr content ($\mu\text{g}/\text{ml}$)..... | 58 |
| TABLE 16: IR spectral data of (γ max Cm^{-1}) in sample (1) TA | 73 |
| TABLE 17: IR spectral data of (γ max Cm^{-1}) in sample (2 and 3) SH... | 74 |
| TABLE 18: IR spectral data of (γ max Cm^{-1}) in sample (4) NI..... | 74 |
| TABLE 19: IR spectral data of (γ max Cm^{-1}) in sample (5 and 6) LA . | 75 |

LIST OF FIGURES

| | Page No |
|---|----------------|
| Figure 1: The separating funnel filled with the treated oil..... | 32 |
| Figure 2: Distilled water added to the treated oil in the separating Funnel..... | 33 |
| Figure 3: Treated oil + distilled water were shaken (emulsion formed)..... | 33 |
| Figure 4: Left for 5 minutes (separation of distilled water from the treated oil was shown)..... | 34 |
| Figure 5: Increasing time purifies the water at the bottom of the funnel(emulsion becomes on top)..... | 34 |
| (Figure 6: Repeating of the experiment (washing with distilled water several times, the emulsion was separated in a conical flask 500 ml..... | 35 |
| Figure 7: The contents of the flask were heated for 5 minutes at 40°C after the addition of sodium hydroxide solid (to be sufficient to neutralize the acid)..... | 35 |
| Figure 8: The contents of the flask after the addition of solid sodium hydroxide, heating for 5 minutes and shaking some of the sodium hydroxide dissolved, and the oil) started to appear)..... | 36 |
| Figure 9: Shows formation of oil with reddish color after heating for more 5 minutes and shaking, all sodium hydroxide dissolved and the excess separated with water at the bottom of the flask..... | 36 |
| Figure 10: Sample 1 [Ta] recycled, used and new..... | 37 |
| Figure 11: Sample 2 [SH] recycled, used and new..... | 37 |

| | | |
|------------|--|----|
| Figure 12: | Sample 3 [SH] recycled, used and new..... | 38 |
| Figure 13: | Sample 4 [NI] recycled, used and new..... | 38 |
| Figure 14: | Sample 5 [LA] recycled, used and new..... | 39 |
| Figure 15: | Sample 6 [LA] recycled, used and new..... | 39 |
| Figure 16: | Sample 7 [TASHNILA] used and recycled..... | 40 |
| Figure 17: | Ubbelhode viscometers with oil bath..... | 41 |
| Figure 18: | Flash point apparatus..... | 42 |
| Figure 19: | Automatic potentiometric titrator..... | 44 |
| Figure 20: | Automatic density meter..... | 45 |
| Figure 21: | X-ray apparatus..... | 46 |
| Figure 22: | Shows viscosity at 100 °C/cSt..... | 48 |
| Figure 23: | Shows viscosity at 40 °C/cSt..... | 49 |
| Figure 24: | Shows flash point °C..... | 50 |
| Figure 25: | Shows Total Base Number (T.A.N) mg KOH/g..... | 51 |
| Figure 26: | Shows Total Acid Number (T.B.N) mg KOH/g..... | 52 |
| Figure 27: | Shows density at 15 °C..... | 53 |
| Figure 28: | Shows Zn ppm..... | 54 |
| Figure 29: | Shows Ca ppm..... | 55 |
| Figure 30: | Shows ash content g %..... | 56 |
| Figure 31: | Shows Ni content (µg/ml)..... | 57 |
| Figure 32: | Shows Ca content (µg/ml)..... | 58 |
| Figure 33: | Infrared spectrum of sample 1 (TA new)..... | 59 |
| Figure 34: | Infrared spectrum of sample 1 (TA used)..... | 59 |
| Figure 35: | Infrared spectrum of sample 1 (TA recycled)..... | 60 |
| Figure 36: | Infrared spectrum of sample 2 &3 (new SH)..... | 60 |
| Figure 37: | Infrared spectrum of sample 2 (used SH)..... | 61 |
| Figure 38: | Infrared spectrum of sample 2 (recycled SH)..... | 61 |
| Figure 39: | Infrared spectrum of sample3 (used SH)..... | 62 |

| | | |
|------------|---|----|
| Figure 40: | Infrared spectrum of sample 3 (SH recycled)..... | 62 |
| Figure 41: | Infrared spectrum of sample4 (NI new)..... | 63 |
| Figure 42: | Infrared spectrum of sample4 (NI used)..... | 63 |
| Figure 43: | Infrared spectrum of sample 4 (NI recycled)..... | 64 |
| Figure 44: | Infrared spectrum of sample 5 &6 (LA new)..... | 64 |
| Figure 45: | Infrared spectrum of sample5 (LA. used)..... | 65 |
| Figure 46: | Infrared spectrum of sample 5 (LA recycled)..... | 65 |
| Figure 47: | Infrared spectrum of sample 6 (LA used)..... | 66 |
| Figure 48: | Infrared spectrum of sample 6 (LA recycled)..... | 66 |
| Figure 49: | Infrared spectrum of sample 7 (TASHNILA used)..... | 67 |
| Figure 50: | Infrared spectrum of sample 7(TASHNILA recycled)... | 67 |