

(RESEARCH ARTICLE)



Comparative study of ultrasonic processor to blending kettle for production of lubricants

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Abstract

Due to the high cost of energy needed in traditional (blending kettle) lube oil blending/manufacturing for viscosity change and the need for specialised lubricants in batches of 1 to 10 tons, it has been found to be beneficial to use ultrasound method for lube oil blending and dispersion of additives and viscosity change. This removes the need for heating, using insulated vessels/blending kettles, as well as high powered agitators, thereby giving huge energy savings and reducing dramatically the carbon footprint. 3,000 litres of lube oil can be manufactured in one hour using a 1.5kw tubular ultrasonic processor without heating, agitation or moving parts unlike the traditional blending method otherwise called blending kettle with the same capacity which manufactures 3,000 litres in 7.5 hours with enormous amount of energy and heat involved. Furthermore, using the ultrasonic method eliminates production delays arising from heating and cooling and mixing high quality products hence aids continuous operation.

Keywords: Blending kettle; Lubricant; Ultrasonic; Oil and manufacture

1. Introduction

Lubricants or lubricating oil can be produced initially only by using the traditional or conventional blending method called blending kettle. Now, a new innovative approach has been developed presently in the UK called Ultrasonic Processor; this method is primarily based on the principle of ultrasound from sono-chemistry (Hilsonic Process Limited, 2018).

Due to the increase in carbon footprint in the atmosphere resulting from lubricating oil blending/production using the traditional method (blending kettle) and the associated high cost of energy required for viscosity change and the need for specialised lubricants, it was imperative to adopt alternative method for blending and manufacturing of lubricating oils and dispersion of additives and viscosity change (Vmets, 2008).

The existing technology otherwise called blending kettle involves charging of base oils into a blending vessel through a flow indicator in fixed proportions and then dehydrated at atmospheric pressure after which additives are added as improvers (Arslan Enginery, 2021). As stated by oil product formula, the lubricant base oil materials and additives are usually added into a mixing or blending kettle in proportions and later mixed evenly by mechanical agitation or stirring for a longer period. The product is then transferred to filling points, typically in containers or kegs via a storage vessel, after cooling for several hours. (Vmets, 2008).

The new technology otherwise called Ultrasonic Processor which is based primarily on ultrasound technology originated from the principle of sonochemistry; sonochemistry is a branch of chemical research that deals with the chemical effects and applications of ultrasonic waves (ultrasound technology) i.e. sound at high frequencies greater than the upper limit of human hearing (Pirro et al., 2016). The ultrasonic tubular processor is a 4" diameter processor

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that is made of stainless-steel pipe (Hilsonic, 2018). The processor is 1.5m long with a thickness of 2” and has two flanges of 150# class each at both ends of the processor. Within the thickness of the processor is embedded seventy-two transducers in which piezo-crystals are attached to; the piezo-crystals provide piezo-electric effect when energy is passed to it, i.e., when powered, with the help of the transducers, electrical energy is converted to ultrasound energy (or mechanical energy which involves the movement of the crystals).

The ultrasonic tubular processor is connected to the control panel which receives power from 13 amps or 15 amps power supply. The control panel helps to ensure the required power is send to the processor in a manner not to damage the processor. The control panel is also advised to be connected to a power surge especially in regions or countries where power supply is not sTable (Stanley, 2020).

The ultrasound technology (ultrasonic processor) involves the use of piezoelectric effect (using piezo crystals) which converts electrical energy into kinetic or mechanical energy with the aid of transducers; this is how ultrasound transducers produce sound waves.

Large volumes of lube oils can be produced quickly with ultrasound technology using a tubular processor without heating, cooling, agitation, or moving parts. The heating, cooling, and mixing of premium lube oil products also no longer cause production delays when using the ultrasonic processor technology method (Arslan, 2021).

2. Material and methods

2.1. Setup Procedure

2.1.1. Procedure for Ultrasonic Processor (New Technology)

25m length hose was cut into 5 different lengths; 5 m length (used to connect the IBC plastic tank to the Tee), 4m length (used to connect the first side of the tee to 100 litres plastic drum), 3.5m length (used to connect the 2nd side of the tee to the suction side of the gear pump), 5.5 m length (used to connect the discharge side of the gear pump to the suction side of the ultrasonic processor), 7m length (used to connect the discharge side of the ultrasonic processor back to the IBC plastic tank of 1,000 litres capacity). Both sides of each of the hose lengths were all secured with 2” galvanized nipples, camlock couplings and 2” clamps. This was to ensure proper hook up and tight connection to avoid leakages or air bubbles from forming to prevent pump cavitation. Figure 3.1 is the setup showing how the connections were made.

2.1.2. Procedure for Blending Kettle (Existing Technology)

General checks on the already installed two heavy wall steel tanks (blending kettle) was carried out before filling the vessels with base oil and additives; bump test was done on the high powered agitator and the oil transfer pumps; the temperature gauge on top of the blending kettle was checked to ensure calibration was up to date; power source was also confirmed ok before energizing the control panels for the blending kettle and the oil transfer pump.

2.2. Production of 1,000 Litres of Monograde Diesel Engine Oil/Generator Oil (Sae 40) Using Ultrasonic Processor (Ultrasound Technology) & Blending Kettle (Traditional Method)

Table 1 Formulation Used and Weight % for SAE 40 (diesel engine/generator oil)

S/N	Material Input	Type	(Weight %)	Volume (L)
1	HVI SN 500	Base Oil	6.15	61.5
2	HVI 150 BS TK 37	Base Oil	60.85	608.5
3	HVI 150 BS TK 32	Base Oil	11.35	113.5
4	APL 700 LZ3589D	Additive	21.65	216.5
TOTAL			100%	1000 L

2.2.1. Experimental Procedure (Experiment 1a)

Applying Ultrasonic Processor Method (Ultrasonic Processor) Without Using Additive Container

Accurately 6.15% weight (61.5 L) of APL 700 (LZ3589D) additive was measured using a 20-litre calibrated container and transferred into the 100 litres plastic drum. Three (3) different types of base oils were measured using the oil flow meter and transferred into the 1,000 litres IBC plastic tank; HVI SN 500 (60.85% weight or 608.5 L), HVI 150 BS TK 37 (11.35% weight or 113.5 L), and HVI 150 BS TK 32 (21.65% weight or 216.5 L).



Figure 1 Process setup of the ultrasonic processor at Techno Oil facility

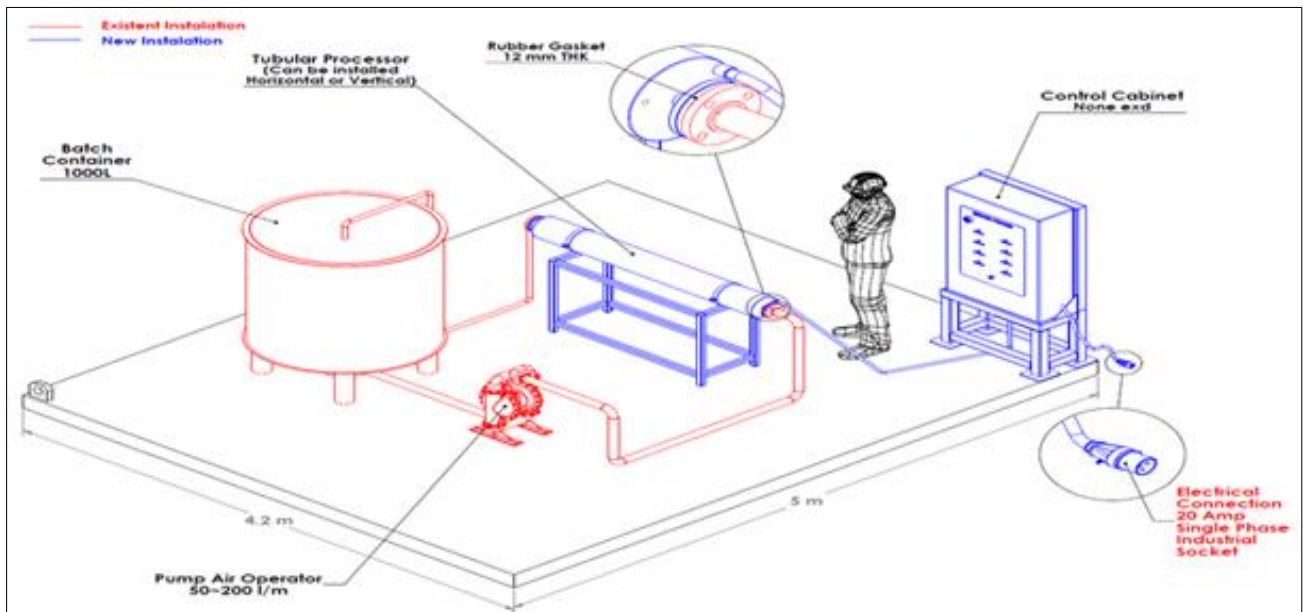


Figure 2 Diagram layout of the ultrasonic processor setup without additive container

From Figure 1 above, the control panel as well as the pump were both connected to separate power sources as shown. The ultrasonic processor was energised by turning on the control switch on the control panel. A slight vibrating sound was heard to indicate that the ultrasonic processor was energised. The processor was allowed for five minutes after which the pump was energised and the ball valve on the IBC tank opened to allow flow through the processor to the IBC tank. As the fluid (base oil + additive) flowed through the processor, a hand stirrer (manual) measuring 2m long was used to stir the lube oil in the IBC tank to reduce additive settling below the IBC tank.

The process was allowed to flow through the processor for 3 cycles after which a sample (2.5 litres) was collected for QC laboratory analysis. After the 3rd cycle was attained, the ball valve on the IBC tank was closed and few seconds later,

the pump was shut down. The ultrasonic processor was also shut down by turning off the power switch and disengaging the control switch on the control panel. The process (3 cycle operation) lasted approximately 26 minutes.

2.2.2. Experimental Procedure (Experiment 1b): Revised Method (Ultrasonic Processor)

The same experiment was carried out but this time a 2" Tee (galvanized steel) was introduced; this was to avoid manual stirring thereby introducing a separate plastic drum that took inventory of the additives as can be seen in Figure 3 below.

The same weight percent of raw materials used in the first experiment was also used to carry out this experiment; exactly 6.15% weight (61.5 L) of APL 700 (LZ3589D) additive was measured using a calibrated container and transferred into the 100 litres plastic drum. Three (3) different types of base oils were measured using the oil flow meter and transferred into the IBC plastic tank; HVI SN 500 (60.85% weight or 608.5 L), HVI 150 BS TK 37 (11.35% weight or 113.5 L), and HVI 150 BS TK 32 (21.65% weight or 216.5 L).



Figure 3 Ultrasonic processor method with introduction of separate additive container

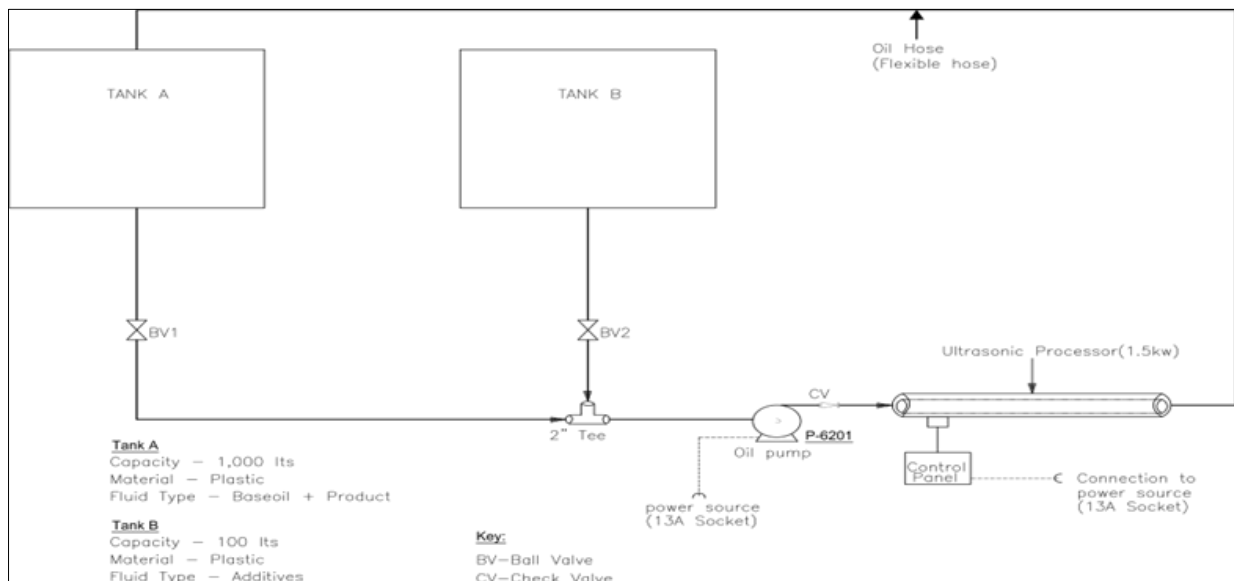


Figure 4 Diagram layout of ultrasonic processor method with additive container

From Figure 3 above, the control panel as well as the pump are both connected to separate power sources (13A sockets) as shown. The ultrasonic processor was energized by turning on the control switch on the control panel. A little vibrating sound was heard to alert us that the ultrasonic processor was energized. The processor was allowed for five minutes after which BV1 was opened (with BV2 still closed) to allow base oil flow to the suction side of the pump. At this point,

the pump was energized by turning on the pump switch (where it was plugged) and the temperature of the base oil taken. As the base oil from the IBC tank flowed through the ultrasonic processor via the pump, BV2 still remained closed until the base oil had completely circulated through the processor. When the complete circulation was achieved, BV1 was then closed and immediately BV2 opened to allow additive circulation through the processor via the pump to the IBC tank. Once the additive has fully circulated, BV2 was then closed and BV1 opened again to allow (now mixture of base oils and additive) flow through the ultrasonic processor via the pump back into the IBC tank.

The process was allowed to flow through the processor for 3 cycles after which sample (3 litres) was collected for QC laboratory analysis and the temperature of the lubricant at the downstream of the processor was taken and recorded. After the 3rd cycle was attained, BV1 was closed and few seconds later, the pump was shut down. The ultrasonic processor was also shut down by turning off the power switch on the control panel. The process (3 cycle operation) lasted approximately 20 minutes. The inlet and outlet temperatures obtained were 26.3 and 27.2 °C respectively.

2.2.3. Experimental Procedure (Experiment 1c): Blending Kettle (Traditional Method)

Accurately 6.15% weight (61.5 L) of APL 700 (LZ3589D) additive was measured using a 20 litre calibrated container and transferred into the blending kettle of 1,000 L. Three (3) different types of base oils were measured using the oil flow meter and transferred into the blending kettle; HVI SN 500 (60.85% weight or 608.5 L), HVI 150 BS TK 37 (11.35% weight or 113.5 L), and HVI 150 BS TK 32 (21.65% weight or 216.5 L).



Figure 5 Blending kettle method

The specified base oils and additives were measured using oil flow meter for base oil and calibrated container for additives; both fluids (base oil + additives) were then transferred into the blending kettle. Later, the control switch of the blending kettle and the high-powered agitator were energized. The inlet temperature was measured to be 26.30°C. As the fluids boiled, it also created a vortex movement with the help of the agitator which ensured thorough mixture of both fluids (base oil & additives). This operation was allowed to boil for two (2) hours at 68.8 °C after which the unit was shut down by switching off the blending kettle control switch as well as powering off the mechanical agitator. The product realized was allowed to cool for 30 minutes before sample (3 L) was taken for QC laboratory analysis.

2.3. Production Of 1,000 Litres of Marine Grade Sae 30 Engine Oil Using Ultrasonic Processor (New Technology) & Blending Kettle (Existing Technology)

Table 2 Formulations Used and Weight % for SAE 30 (Marine Oil)

S/N	Material Input	Type	(Weight %)	Volume (L)
1	HVI SN 500	Base Oil	95.31	953.1
2	AP 700 (3589D)	Additive	3.33	33.3
3	AP (D1212)	Additive	1.36	13.6
TOTAL			100%	1000 L

2.3.1. Experimental Procedure (Experiment 2a): Using Ultrasonic Processor

95.31 Weight % (953.1 L) of HVI SN 500 (base oil) was accurately measured using the lube oil flow meter and transferred into the ibc tank. After transferring the base oil into the ibc tank, 3.33 weight % (33.3 L) of AP 700 (3589D) additive and 1.36 weight % (13.6 L) of AP (D1212) additive were also measured using a calibrated container and discharged into the additive drum. However, before measuring the additives, they were preheated in a stainless-steel tank at 650 °C and cooled for 10 minutes as shown in Figure 6 below; this was done to enable the additives (thinning) to flow easily through the flexible hose to the processor via the pump. The inlet and outlet temperatures obtained were 26.4 and 27.5 °C respectively.



Figure 6 Additives Preheating Tank for SAE 30 marine oil



Figure 7 Marine grade SAE 30 blending using ultrasonic processor

Before transferring the additives into the additives drum, it was allowed to cool for about 10 minutes; this was to avoid potential softening of the plastic drum and the flexible oil hose which may later lead to leaks. After the additives were transferred into the drum, the blending process was done applying the same process as the revised process above: the control panel as well as the pump were both connected to separate power sources (13A sockets) as shown. The ultrasonic processor was energised by turning on the control switch on the control panel. A little vibrating sound was heard to alert us that the ultrasonic processor was energised. The processor was allowed for five minutes after which BV1 was opened (with BV2 still closed) to allow base oil flow to the suction side of the pump. At this point, the pump was energised by turning on the pump switch (where it was plugged). As the base oil from the IBC tank flowed through the ultrasonic processor via the pump, BV2 still remained closed until the base oil had completely circulated through the processor. When the complete circulation was achieved, BV1 was then closed and immediately BV2 opened to allow additive circulation through the processor via the pump to the IBC tank. Once the additive have fully circulated, BV2 was then closed and BV1 opened again to allow (now mixture of base oils and additive) flow through the ultrasonic processor via the pump back into the IBC tank.

The process was allowed to flow through the processor for 3 cycles during which samples (1 liter) were collected at each cycle for QC laboratory analysis. After the 3rd cycle was attained, BV1 was closed and few seconds later, the pump was shut down. The ultrasonic processor was also shut down by turning off the power switch on the control panel. The entire process lasted 24 minutes.

2.3.2. Experiment 2b: Using Blending Kettle Method (Existing Technology) To Produce Marine Grade SAE 30 Lubricant

After the required volume (as per the same weight percent of experiment 2a) of base oil and additives were measured and transferred via the oil transfer pump into the blending kettle using the oil flow meter for base oil and calibrated container for the additives, the control switch of the blending kettle was energized to boil the fluids; as the fluids boiled, it also created a vortex movement due to the high powered agitator that ensures thorough mixture of both fluids (base oil & additives). The inlet temperature measured to be 26.4 °C. This operation was allowed to boil for 2 hours 30 minutes at 69.30C after which the unit was shut down by switching off the blending kettle control switch as well as powering off the mechanical agitator. The product realized was allowed to cool for 30 minutes before sample (3 L) was taken for QC laboratory analysis.



Figure 8 Blending kettle used for Marine Grade SAE 30 Lubricant

2.4. Production Of 1,000 Litres of Multigrade Motor Engine Oil (Sae 20w50) Using Ultrasonic Processor (Ultrasound Technology) & Blending Kettle (Traditional Method)

Table 3 Formulation Used and Weight % for SAE 20W50 (Car/Motor Oil)

S/N	Material Input	Type	(Weight %)	Volume (L)
1	HVI SN 500	Base Oil	75	750
2	HVI 150 BS TK 32	Base Oil	9.5	95
3	HI 5748	Additive	7.5	75
4	HI 9325	Additive	7.7	77
5	V351	Additive	0.3	3
TOTAL			100%	1000 L

2.4.1. Experimental Procedure (Experiment 3a): Applying Ultrasonic Method (Ultrasonic Processor)

Accurately 75 % weight (750 L) of HVI SN 500 base oil was measured using the oil flow meter and transferred into the 1000 litres IBC container. Three (3) different types of additives were measured using a calibrated container and

transferred into the 100 litres plastic drum; HI 5748 (9.5% weight or 95 L), HI 9325(7.7 % weight or 77 L), and V351 (0.3 % weight or 3 L).

The same sequence used (as in experiments 1b and 2a above) in operating the ultrasonic processor was deployed to produce the SAE 20W50 lubricant. The sequence is as shown below:

Ensure all connections as per Figure 7, Ensure power availability, Start the Ultrasonic Processor through its control panel, Start the gear pump through its control panel, Flow the base oil and the additives through the ultrasonic processor by their various valve controls, Lubricant realization Shut down the gear pump through its control panel, Shut down the ultrasonic processor machine via its control panel. The product was realized after 3 cycles of operation i.e. 21 minutes. The inlet and outlet temperatures obtained were 26.1 and 27 °C respectively.

2.4.2. Experimental Procedure (Experiment 3b): Using The Blending Kettle Method

Accurately 75% weight (750 L) of HVI SN 500 base oil was measured using the oil flow meter and transferred into the blending kettle via the oil pump. Three (3) different types of additives were measured using a calibrated container and transferred into the same blending kettle using a dosing pump; HI 5748 (9.5% weight or 95 L), HI 9325(7.7% weight or 77 L), and V351 (0.3% weight or 3 L). The inlet temperature was measured to be 26.1 °C.

The same sequence of using the blending kettle was deployed to produce the SAE 20W50 lubricant as shown below:

After the required volume (as per the same weight percent of experiment 3a) of base oil and additives were measured and transferred via the oil transfer pump into the blending kettle using the oil flow meter for base oil and calibrated container for the additives, the control switch of the blending kettle was energized to boil the fluids; as the fluids boiled, it also created a vortex movement due to the high powered agitator that ensures thorough mixture of both fluids (base oil & additives). This operation was allowed to boil for 2 hours at 67.2 °C after which the unit was shut down by switching off the blending kettle control switch as well as powering off the mechanical agitator. The product realized was allowed to cool for 30 minutes before sample (3 L) was taken for QC laboratory analysis.

2.5. Production Of 1,000 Litres of 2 Stroke Oil (2t Engine Oil; SAE 10W40) Using Ultrasonic Processor And Blending Kettle)

Table 4 Formulation Used and Weight % for SAE 10W40 (Motorcycle Oil)

S/N	Material Input	Type	(Weight %)	Volume (L)
1	900 N	Base Oil	68	680
2	Motor Oil	Motor Oil	30	300
3	BP 398	Additive	2	20
TOTAL			100%	1000 L

2.5.1. Experimental Procedure (Experiment 4a): Applying Ultrasonic Method (Ultrasonic Processor)

Accurately 68 % weight (680 L) of 900 N was measured using the oil flow meter and transferred into the IBC tank, 30 % weight (300 L) of a typical motor oil was measured using the oil flow meter and transferred into the IBC tank, and 2 % weight (20 L) of BP 398 additive was measured using a calibrated container and transferred into the additive plastic drum.

The same sequence used (as in experiments 1b and 2a above) in operating the ultrasonic processor was deployed to produce the SAE 10W40 2T motorcycle oil. The sequence is as shown below:

Ensure all connections as per Figure 8, Ensure power availability, Start the Ultrasonic Processor through its control panel, Start the gear pump through its control panel, Flow the base oil and the additives through the ultrasonic processor by their various valve controls, Lubricant realization Shut down the gear pump through its control panel, Shut down the ultrasonic processor machine via its control panel. The product was realized after 3 cycles of operation at approximately 19 minutes. The inlet and outlet temperatures obtained were 26.1 and 26.8 0C respectively.

2.5.2. Experimental Procedure (Experiment 4b): Using the blending kettle method

Accurately 68 % weight (7680 L) of 900 N base oil was measured using the oil flow meter and transferred into the blending kettle via the oil pump, 30 % weight (300L) of a typical motor oil was measured using the oil flow meter and transferred into the blending kettle via the oil transfer pump, while 2 % or 20 L of BP 398 additive was measured using a calibrated container and transferred into the blending kettle.

The inlet temperature was measured to be 26.1 °C.

The same sequence of using the blending kettle was deployed to produce the SAE 10W40 lubricant as shown below:

After the required volume (as per the same weight percent of experiment 3a) of base oil and additives were measured and transferred via the oil transfer pump into the blending kettle using the oil flow meter for base oil and calibrated container for the additives, the control switch of the blending kettle was energized to boil the fluids; as the fluids boiled, it also created a vortex movement due to the high powered agitator that ensures thorough mixture of both fluids (base oil & additives). This operation was allowed to boil for 1 hour 50 minutes at 65.50C after which the unit was shut down by switching off the blending kettle control switch as well as powering off the mechanical agitator. The product realized was allowed to cool for 30 minutes before sample (3 L) was taken for QC laboratory analysis.

2.6. Quality Control Laboratory Analysis

The following QC laboratory instruments were used to conduct the laboratory analysis:

Hydrometer, Viscometer, Viscometer Bath @ 400 °C, Viscometer Bath @ 1000 °C, Flash Point Tester, Flash Point Cup, Pour Point Tester, Pour Point Cup, X-ray Fluorescent (XRF), Hot Plate, and Thermometers

2.6.1. Determination of Specific Gravity

500ml measuring cup was used to measure out 250ml of the diesel motor/generator oil sample and poured into 500ml measuring cylinder. Later, a thermometer (0 °C to 80 °C) was used to check the temperature after confirming no bubbles exist in the measuring cylinder. After checking the temperature, the hydrometer was inserted in the measuring cylinder and the reading taken in kg/l. After taking the reading, the temperature was again checked to ensure $\Delta T \leq 0.1^\circ\text{C}$.

2.6.2. Determination of the Oil Viscosity @ 400 °C

20 litres of silicon oil was measured using 20 litres plastic container and poured inside the viscometer bath. The on/off switch on the bath was then switched on after ensuring connection to power source. The bath was then heated to 400C as can be seen on the display. However, a thermometer (00C to 2000C) was also used to confirm that the temperature reading was maintained at 400 °C. Later, the suction pump was used to suck the oil sample from the beaker and poured inside the viscometer. The viscometer handle was then used to place it inside the viscometer bath and later heated for 30 minutes. After heating for 30 minutes, the bath was powered off as the oil in the viscometer was already settled at the base of the viscometer. The suction pump was again used to suck the oil to the upper marked point of the viscometer and then placed again the viscometer bath. As the bath was switched on again, immediately a stopwatch was used to monitor the time it took the oil in the viscometer to drop from the upper marked point to the lower marked point.

2.6.3. Determination of the Oil Viscosity @ 1000 °C

20 litres of silicon oil was measured using 20 litres plastic container and poured inside the viscometer bath. The on/off switch on the bath was then switched on after ensuring connection to power source. The bath was then heated to 1000 °C as can be seen on the display. However, a thermometer (0 °C to 2000 °C) was also used to confirm that the temperature reading was maintained at 1000 °C. Later, the suction pump was used to suck the oil sample from the beaker and poured inside the viscometer. The viscometer handle was then used to place it inside the viscometer bath and later heated for 30 minutes. After heating for 30 minutes, the bath was powered off as the oil in the viscometer was already settled at the base of the viscometer. The suction pump was again used to suck the oil to the upper marked point of the viscometer and then placed again the viscometer bath. As the bath was switched on again, immediately a stopwatch was used to monitor the time it took the oil in the viscometer to drop from the upper marked point to the lower marked point.

2.6.4. Determination of the Flash Point of the Oil Sample

100ml of the oil sample is poured inside the marked point of the flash point cup after which an ASTM thermometer (0 °C – 400 °C) was inserted. The igniter button on the flash point tester was pushed to on position and then passed through

the flash point cup for several times until a pseudo flash was seen. Immediately the pseudo flash was seen, the flash point was obtained which was the reading from the thermometer.

2.6.5. Determination of the Pour Point of the Oil Sample

200ml of the oil sample was poured inside the pour point cup and then a thermometer (200 °C to -800 °C) was inserted in the measuring cylinder. The cylinder was then corked to ensure firm grip and then later placed inside the pour point tester. Normally, the room temperature is 260 °C, but after placing the cylinder inside the pour point tester, the temperature dropped to 200 °C due to its freezing nature. The cylinder was brought out of the tester and it was later slanted after which the oil flowed. The cylinder was again placed inside the tester and was being brought out after every 30C drop. When the oil sample stops flowing after being brought out, you measure the temperature and then add 30 °C. The essence of adding 30 °C is assumed the oil sample has stopped flowing previously.

2.6.6. Determination of the Total Base Number (TBN) of the Oil Sample

0.1 M of perchloric acid was measured and poured inside a burette. Later, a mixture of chlorobenzene and acetic acid (2:1 ratio) which is also called TBN titration solvent was mixed inside a 200 ml measuring cup. Later, 60 ml of the TBN titration solvent mixture was taken and poured inside a 200 ml conical flask. Three (3) drops of the P-Naphtholbenzine was added to the TBN titration solvent mixture and it later turned to orange colour. This was then used to titrate against 0.1 M of the perchloric acid. The titration ended when the solution turned green and then the TBN was calculated using the formula below:

$$TBN = (Titre Value \times Conc. of perchloric acid \times 56.1)/(Weight of Sample Taken) \dots\dots (1)$$

2.6.7. Determination of % Weight of Calcium and Zinc of the Oil Sample

250 ml of the oil sample was measured using the measuring cylinder and then transferred into the XRF cup. The XRF cup was then placed in a sample compartment inside the XRF machine. The on/off switch button of the XRF machine was then pushed to on position and allowed for 30 minutes after which the result was generated and displayed on the XRF machine screen.

2.6.8. Determination of % Sulphated ASH (SO₄) of the oil sample

100ml sample of the oil was poured in a cubicle and placed inside a Bunsen burner and heated to dryness. Later, the sample was allowed to cool and three drops of H₂SO₄ acid was added. It was then placed in a furnace that has been set at 775 °C to burn further for another 30 minutes. After burning for 30 minutes, the sample was brought out and allowed to cool to room temperature. Later, ten drops of distilled water using pipette was added and three drops of a mixture of water + H₂SO₄ acid (ratio 1:1) was added. The solution was then shaken thoroughly and allowed to burn again until white fumes stopped generating. After the white fumes had stopped, it was again placed on the furnace and allowed to burn for additional 30 minutes, after which it was brought down and allowed to cool to room temperature. Then the weight of the cubicle was then taken and recorded as W₂.

% Sulphated ash is thus calculated as:

$$\% SO_4 = (W(2) - \frac{W(1)}{Weight\ of\ sample\ taken}) \times 100 \dots\dots(2)$$

Where,

w₁ = weight of the empty cubicle

w₂ = weight of cubicle after final burning

2.6.9. Determination of % Water Content of the Oil Sample

10ml of the oil sample was measured using the measuring cylinder and poured on the hot plate in order to check for water burning sound. The procedure was again repeated to confirm presence of water in the oil sample. This procedure is also called crackle test.



Figure 9 Viscometer bath

2.7. Calculation of Amount of Heat in the Process

Before calculation of the heat energy, it is imperative to know the specific heat capacities of the various lubricants. Specific heat capacity (SHC) is defined as that amount of heat energy required to raise the temperature of a unit mass of that substance by one Kelvin (Nelkcon et al., 1987).

The heat energy generation is calculated using the formula:

$$Q = mC_p \Delta T \dots\dots\dots(3)$$

- Where,
- m = mass of the substance in kg
- Q = Amount of heat in J
- C_p = Specific heat capacity in J/kg.K
- ΔT = Change in temperature

Detailed calculation of heat energy used to use both ultrasonic processor and blending kettle are contained in Appendix 2.

2.8. Energy Consumption Calculation

To obtain the energy consumed using both methods, we have:

$$E = P X (t/1000) \dots\dots\dots(4)$$

- Where
- E = Energy consumed or used in kWh
- P = Power rating in W
- t = Time used per day in h

3. Results and discussion

3.1. Production of four types of lubricants

Four different lubricants (SAE 40, SAE 30, SAE 20W50, and SAE 10W40) were manufactured using both the ultrasonic processor and the blending kettle methods. The lubricants were seen to be homogenous hence confirming thorough mixture of base oil and additives to produce lubricants.

3.2. Analysis of the QC laboratory test results for both methods of lubricants manufacture

The test results obtained from laboratory analysis of lubricants manufactured using the ultrasonic processor and the blending kettle as shown on Tables 5, 6, 7, and 8 conform to specification as per their applicable ASTM standards. For specific gravity from Table 5, 0.885 was obtained using ultrasonic processor while 0.887 was obtained using the blending kettle; these results conform to ASTM D1298 which stated that the specific gravity must fall within the range of 0.88 – 0.89. For viscosity at 40 °C, 170.3 – 170.6 cSt was obtained using the ultrasonic processor, while 170.5 – 171.2 cSt was obtained using the blending kettle; the results show that the one obtained using the ultrasonic processor conforms to ASTM D445 which stated that the range must be within 170 – 171 cSt, while the one obtained using the blending kettle was marginally above the stipulated range. For other control test results as shown on the Tables confirm that they are in conformance with the standard specifications according to their respective ASTM standards as shown on Tables 5, 6, 7, and 8.

Table 5 Result Of (Diesel Engine Oil SAE 40: CF/SF)

Control tests	Method	Specification	Test results a			Test results b		
			A1	A2	A3	B1	B2	B3
APPEARANCE	Visual	C & B	C & B	C & B	C& B	C & B	C & B	C & B
SPECIFIC GRAVITY @ 15°C	ASTM D1298	0.88 – 0.90	0.885	0.885	0.885	0.887	0.887	0.887
VISCOSITY @ 40°C (cSt)	ASTM D445	170 – 171	170.3	170.6	170.5	170.5	170.8	171.2
VISCOSITY @ 100°C (cSt)	ASTM D445	16.2 – 16.8	16.6	16.4	16.7	16.4	16.4	16.5
VISCOSITY INDEX	ASTM D2270	95 Min.	98	97	98	97	97	96
FLASH POINT (°C)	ASTM D92	210 Min.	211	212	211	212	211	212
POUR POINT (°C)	ASTM D97	-9 Max.	-9	-9	-9	-9	-9	-9
TBN	ASTM D2896	5 Min.	6	6	6	6	6	6
CALCIUM (% wt)	SMS 2777-91	-	-	-	-	-	-	-
ZINC (% wt)	SMS 2777-91	-	-	-	-	-	-	-
SULPHATED ASH (% wt)	ASTM D874	0.45 – 0.6	0.51	0.51	0.51	0.52	0.52	0.52
WATER CONTENT	Crackle	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Test result A - Using ultrasonic processor equipment; Test result B - Using the conventional blending kettle; A1 = QC laboratory result conducted immediately after the experiment for Ultrasonic Processor; A2 = QC laboratory result conducted after 24 hours of the experiment for Ultrasonic Processor; A3 = QC laboratory result conducted after 90 days of experiment for Ultrasonic Processor; B1 = QC laboratory result conducted immediately after the experiment for Blending Kettle; B2 = QC laboratory result conducted after 24 hours of the experiment for Blending Kettle; B3 = QC laboratory result conducted after 90 days of experiment for Blending Kettle

Table 6 Result Of Marine Grade SAE 30 Engine Oil

Control tests	Method	Specification	Test results a			Test results b		
			A1	A2	A3	B1	B2	B3
APPEARANCE	Visual	C & B	C & B	C & B	C & B	C & B	C & B	C & B
SPECIFIC GRAVITY @ 15°C	ASTM D1298	Report	0.889	0.889	0.889	0.889	0.889	0.889
KV. @ 40°C (cSt)	ASTM D445	158.70 – 159.20	158.97	159.04	159.01	158.68	158.91	158.88
KV. @ 100°C (cSt)	ASTM D445	14.1 – 16.3	15.2	15.2	15.4	14.8	14.4	14.7
VISCOSITY INDEX	ASTM D2270	95 Min	100	100	99	96	99	98
FLASH POINT (°C)	ASTM D92	220 Min	244	242	242	239	234	240

POUR POINT (°C)	ASTM D97	-9 Max	-8	-8	-8	-9	-9	-9
TBN	ASTM D2896	5 Min	5.77	5.77	5.77	5.75	5.75	5.75
SO4 ASH, % wt	ASTM D874	0.768 ± 10%	0.795	0.794	0.794	0.775	0.777	0.777
Ca	XRF	0.09474 ± 10%	0.101	0.101	0.101	0.101	0.101	0.101
Zn	XRF	0.0416 ± 10%	0.041	0.042	0.042	0.044	0.043	0.041
WATER CONTENT	Crackle	NIL	Nil	Nil	Nil	Nil	Nil	Nil

Table 7 Test Result of SAE 20W50 (CAR/MOTOR OIL)

Control tests	Method	Specification	Test results a			Test results b		
			A1	A2	A3	B1	B2	B3
APPEARANCE	Visual	C & B	C & B	C & B	C & B	C & B	C & B	C & B
SPECIFIC GRAVITY @ 15°C	ASTM D1298	0.88 – 0.89	0.885	0.885	0.885	0.885	0.885	0.885
KV. @ 40°C (cSt)	ASTM D445	169 – 170	169.5	169.3	169.3	169.6	169.2	169.4
KV. @ 100 °C (cSt)	ASTM D445	18.7-19.0	18.86	18.84	18.83	18.79	18.82	18.85
VISCOSITY INDEX	ASTM D2270	126 ± 0.2	126.08	126.02	126.06	126.03	126.03	126.09
FLASH POINT (°C)	ASTM D92	235 – 236.5	236	236	236.1	235.6	235.4	235.8
POUR POINT (°C)	ASTM D97	-22 Max	-21	-21	-21	-21	-21	-21
FOAMING TENDENCY	ASTM D2892	20/0	20/0	20/0	20/0	20/0	20/0	20/0
WATER CONTENT	Crackle	NIL	NIL	NIL	NIL	<0.020	<0.020	<0.020

Table 8 Result Of 2T Engine Oil For Motorcycle (SAE 10W40)

Control tests	Method	Specification	Test results a			Test results b		
			A1	A2	A3	B1	B2	B3
APPEARANCE	Visual	C & B	C & B	C & B	C & B	C & B	C & B	C & B
COLOUR	ASTM D1298	Report	NOT DYED	NOT DYED	NOT DYED	NOT DYED	NOT DYED	NOT DYED
SPECIFIC GRAVITY @ 15 °C	ASTM D445	0.880 – 0.890	0.883	0.883	0.883	0.885	0.885	0.885
VISCOSITY @ 40 °C (cSt)	ASTM D445	136 - 141	138.96	138.45	138.77	139.39	139.04	139.31
VISCOSITY @ 100 °C (cSt)	ASTM D2270	13.00 – 16.30	14.55	14.48	14.5	13.73	13.95	13.87
VISCOSITY INDEX	ASTM D92	90 - 94	92	92	92	93	93	93
FLASH POINT (°C)	ASTM D97	200 - 207	202	202	202	202	202	202

POUR POINT (°C)	ASTM D2896	-9 Max	-9	-9	-9	-9	-9	-9
TBN	ASTM D874	2.5 ± 10%	2.57	2.57	2.57	2.57	2.57	2.57
MAGNESIUM % wt	XRF	± 10%	-	-	-	-	-	-
SULPHATED ASH % wt	XRF	± 10%	-	-	-	-	-	-
WATER CONTENT	Crackle	< 0.005	NIL	NIL	NIL	0.001	0.001	0.001

3.3. Analysis of the Amount of Heat involved in the process.

From Table 9, the amount of heat involved in the manufacturing of SAE 40 (diesel engine/generator oil) using the blending kettle was fifty (50) times greater than using the ultrasonic processor to manufacture the same product. For SAE 30 (Marine oil), the blending kettle was approximately forty-three (43) times greater than the ultrasonic processor. For SAE 20W50 (car/motor oil), the blending kettle was approximately forty-nine (49) times greater than the ultrasonic processor. Similarly, for SAE 10W40 (motorcycle oil), the blending kettle was approximately sixty (60) times greater than the ultrasonic processor. This confirms that the ultrasonic processor generates minimal amount of heat hence nearly zero carbon footprint generation (Hilsonic, 2018).

Table 9 Amount Of Heat Involved In The Process (For Both Ultrasonic Processor And Blending Kettle)

S/N	METHOD	SAE 40	SAE 30	SAE 20W50	SAE 10W40
1	Ultrasonic Processor	1,465.56 kJ	1,800.98 kJ	1,457.60 kJ	1,127.49 kJ
2	Blending Kettle	74,472.75 kJ	76,692.33 kJ	70,928.33 kJ	67,297.17 kJ

3.4. Analysis of the amount of Energy required for production of lubricants using both methods.

From Table 10, enormous amount of energy is required for blending kettle while very little energy is required for ultrasonic processor. For SAE 40, 218.2 kWh was used for blending kettle while 1.865 kWh was used for ultrasonic processor. The other energy used for SAE 30, SAE 20W50, and SAE 10W40 for both blending kettle and ultrasonic processor are 272.75 kWh, 218.2 kWh, 245.475 kWh and 2.24 kWh, 1.96 kWh, 1.775 kWh respectively. Alex (2022) in his work obtained 1,962 kWh for blending kettle and 8 kWh for ultrasonic processor for the manufacture of 10 MT of lubricants. These are in close agreement with the values obtained (Table 10).

Table 10 Energy Consumption for Both Ultrasonic Processor And Blending Kettle

S/N	METHOD	SAE 40	SAE 30	SAE 20W50	SAE 10W40
1	Ultrasonic Processor	1.865 kWh	2.24 kWh	1.96 kWh	1.775 kWh
2	Blending Kettle	218.2 kWh	272.75 kWh	218.2 kWh	245.475 kWh

3.5. Comparative Analysis of using Ultrasonic Processor to Blending Kettle for Lubricant Manufacture

Table 11 Temperature Readings obtained during the use of Ultrasonic Processor

S/N	Description of lubricants	T _{in} (°C)	T _{out} (°C)
1	Diesel Engine/Generator Oil (SAE 40)	26.3	27.2
2	Marine Oil (SAE 30)	26.4	27.5
3	Motor/Car Oil (SAE 20W50)	26.1	27.0
4	2T Engine Oil (10W40)	26.1	26.8

From Tables 11, and 12, it is substantiated that the temperature difference (ΔT) for ultrasonic processor is approximately 1 °C while that for blending kettle is between 39.4 °C and 42.5 °C. Since temperature is a function of specific heat capacity (Glenn, 2016), Table 4.7 clearly shows that the lubricants produced using the blending kettle have higher specific heat capacities than the lubricants produced using the ultrasonic processor because of higher blending temperatures. The higher temperatures seen using the blending kettle which ultimately generates large amount of heat is indicative that carbon footprint generation will be enormous.

Table 12 Temperature Readings Obtained during the use of Blending Kettle

S/N	Description of lubricants	T _{in} (°C)	T _{out} (°C)
1	Diesel Engine/Generator Oil (SAE 40)	26.3	68.8
2	Marine Oil (SAE 30)	26.4	69.3
3	Motor/Car Oil (SAE 20W50)	26.1	67.2
4	2T Engine Oil (SAE 10W40)	26.1	65.5

4. Conclusion

This research work shows that the ultrasonic processor technology manufactures lubricants in a better manner than the blending kettle technology. It is evident that the use of ultrasonic processor technology for the manufacture of lubricants offers more benefits than the use of the blending kettle technology for the same purpose. Table 5.1 below shows the findings during this work. In conclusion, as compared to the traditional blending kettle approach, making lubricants in an ultrasonic processor has several benefits. The ultrasonic processor is lightweight and inexpensive since it is housed in a plastic tank and has plastic connections and a flexible oil pipe. It has a lower ecological foot print since it needs less room and uses less power to function. The process is rapid, producing usable lubricants without the need for cooling. Due to the lack of mechanical moving components, maintenance is cheap. The blending kettle approach, on the other hand, requires a thick wall steel tank, costly fittings, and carbon steel pipelines, which raises both the upfront and ongoing costs. Heat causes increased volume and power consumption as well as a large carbon impact. Continuous operation is more challenging since the process takes longer and cooling is required before usage. There are a lot of moving components, thus maintenance is expensive.

Compliance with ethical standards

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No conflict of interest to be disclosed.

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