



Utilization Of Efficient And Environmentally Friendly Metal Cutting Fluid (Mcf) By Glycolyzing Of Edible And Nonedible Oil

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Abstract

The using of metal working cutting fluids increasing day by day for improvement of fabrication of metals ,maintenance of cutting tools ,reduce of power for production , cooling and lubricant of metal surface. In this study new renewable metal cutting fluids were prepared based on edible and nonedible oil, these cutting fluids were biodegradable and safe for workers. In this study generated naturally, biodegradable and proficient metal cutting fluids from Jatropha oil, sunflower oil and castor oil. Oil was glycolyzed utilizing polyethylene glycol 600 to deliver the glycolyzed products (J600, S600 and C600) respectively. The prepared compounds were utilized as emulsifiers within the definition for metal cutting fluids in presence of sunflower, castor, and Jatropha oils as ecofriendly oils. That comes about appeared great constancy for prepared glycolyzed oils in water suspensions. Surface tension, pH, specific gravity, kinematic viscosity at 40 °C, and anti-corrosion tests of the arranged preparation appeared satisfactory consequences were it more stable reach to 30 days, high viscosity in use of castor oil reach to 98 cSt, more dispersion and decrease surface tension in case of use castor oil 42 mN/m comparing by printed records for numerous working fluids preparations.

Keywords: Edible and nonedible oils; metal cutting fluids; copper strip.

1. Introduction

The machining manufacturing utilizes enormous amounts of emulsion water with oils for disseminating the cutting device temperature, moving forward surface completion of portions and expanding instrument lifetime. Within the current circumstances, the marketplace for metal cutting is about 1100 million USD [1], also it is assessed to contact 2000 million USD by 2024. Perpetually, working fluid will become defiled by usage, should be arranged toward the climate. It was apparent from writing that cutting fluids involve 16.9% of machining fee [2]. Fig. 1.

Report by National Institute of Occupational Safety and Health [3] appears that inward breath of oil-based metal cutting fluid vaporizers can disturb lung, nose, and throat and has been linked with ceaseless bronchitis, asthma and breaking down of past respiratory issues. Working fluids are fundamentally emulsions oils with water. Soundness of suspensions is identified with improvement of an electrical layer in the oil - water interface. Repulsive forces amid parts of similar charge evade their blend. Erosion of metal

made by water in emulsion and to dodge this, sodium nitrate was utilized as anticorrosive [4]. But constancy, suspensions are tending to microbial growing and bacterial assaults, which can prompt erosion in addition helpless lubrication possessions. Microbial growing is decreased by addition 0.15% biocides by weightiness [5]. Despite the reality that these biocides are antimicrobial, is cancer-causing to specialist's wellbeing they discharge formaldehyde [6].

The work done in maintainable metal cutting fluid is significantly ordered into high-speed dry compound machining of Ti6Al4V, applied to dry orthogonal cutting of aluminum alloy AA2024–T351, using dry cutting and cryogenic cooling in semi-finishing turning of the Ti6Al4V titanium alloy produced by the Additive Manufacturing technology known as Electron Beam Melting when compared to standard flood cooling [7-9], behaviour of Polycrystalline Diamond (PCD) tools when machining Ti–6Al–4V alloy at high speed conditions using high pressure coolant supplies [10], Tool point frequency response functions (FRF), analytical model for tool point FRF of

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micro end mills is presented [11] cold compressed air systems [12], liquid nitrogen, as cryogenic cooling, vapour, gas coolant, during drilling of glass aluminium reinforced epoxy (GLARE) fibre-metal laminates and minimum quality lubrication-MQL [13, 14], and fabrication of composite materials by using banana fibre, glass fibre, epoxy resin and evaluation of mechanical behavior of fabricated composite materials [15].

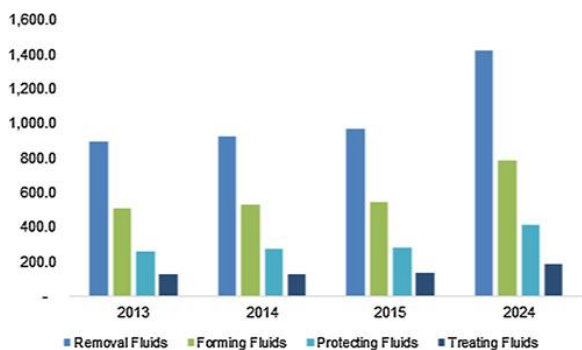


Fig. 1. U.S. Metalworking Marketplace scope, by usage, 2013–2024 (USD million), Worldwide marketplace insights report [16].

Rapeseed and canola oils are better biodegradable lubricants and fewer expensive than synthetic lubricants. They often display very satisfactory act as lubricants [17]. Metal working fluids are divided to three groups; (i) gases (ii) water-soluble fluids and (iii) complete cutting oils. Water-soluble fluids divided as soluble oils, semi-synthetic or synthetic fluids. [18]. In overall, vegetable oils are very smart alternates used for petroleum-based oils due to they are ecofriendly, regenerate, save and easily biodegradable [19, 20]. So, vegetable-based oils are extra probable applicants used for industry as lubricants/MWFs. Numerous surveys are in utilize of numerous vegetable oils to develop new bio-based metal working fluids. Owing to ecofriendly anxieties and rising rules over pollution, the rise in essential for regenerate and ecofriendly lubricants is very predictable. Every year development amount of 7–10% used for naturally promising lubricants is predictable in US marketplace above next rare years likened to an amount of lone 2% for global lubricant marketplace [21]. Advantage of use of vegetable oils are a feasible and regenerate source of ecofriendly oils. Mainstream of vegetable oils contain mainly of tri glycerides that have three long chain fatty acids attached at hydroxyl groups through ester connections. Fatty acids in vegetable oil tri glycerides are completely of alike length, among 14

and 22 carbons extended, with variable intensities of unsaturation [22, 23]. Fig.2 displays chemical structure of triglyceride of vegetable oil, where R1, R2 and R3 are extended chains of carbons and hydrogen atoms, long polar fatty acid chains afford great power lubricant films that reacted powerfully with metallic surfaces, decreasing together roughness and wear. The powerful intermolecular connections are also hardly to changes in temperature provided that a further stable viscosity, or great viscosity coefficient. The likeness in wholly vegetable oil have low viscosities.

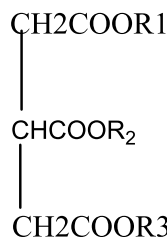


Fig. 2. Triglyceride of different vegetable oil [24].

Advantages and Disadvantages of vegetable oil for using as metal cutting fluid. High biodegradability, Low current constancy, Ecofriendly, Compatibility with flavors by oxidative constancy, High freezing points, Little making price, Deprived erosion defense, Extensive manufacture options Little, In height flashpoints [21]. Poisonousness in every phases of its life. Lubricant preparations are being established on the aids and limits of vegetable oils. Deprived of flavors, vegetable oils did mineral base oils in anti-wear and friction [22, 25], scuffing load capacity [26] and fatigue confrontation [27]. Completely expressed vegetable oil lubricants, in contrast to mineral oil complements, show a lesser factor of friction, equal scuffing load capacity and well pitting fight, but then also poorer thermal and oxidative stability [21, 28-31]. At great loads, vegetable oil-based lubricants come to be considerably fewer active [32]. Vegetable oils are mostly actual as border lubricants as the in height polarization of the full base oil permits strong connections with the lubricated surfaces. Assessed the act of a diversity of mineral and vegetable oil-based cutting fluids in a widespread variety of machining processes and originate that vegetable-based oil formulations showed equivalent or well act than the orientation profitable mineral oil in all processes [33]. In outline, vegetable oils do show numerous wanted features, which make them very good-looking lubricants for numerous applied requests. The main act issues for example small temperature possessions and small fight to oxidative decay are lectured by numerous means as (i) genetic adjustment of oil seed harvest, (ii) chemical adjustment of vegetable-based oils and (iii) reformulation of additional substances [28],[21]. In this research, the use of vegetable oil-

based metal cutting fluids in machining numerous evaluations of steel have been studied in particulars and their requests as stand by to mineral based oil are highlighted.

2. Experimental Techniques

2.1 Chemicals

Poly ethylene glycol (MWt 600 g/mole) was laboratory status and provided as of Sigma Aldrich, Germany. Sunflower, Castor, Jatropha oils, were provided as of Al dawlya, domestic market, Egypt.

2.2 Instrumentation

FTIR Spectroscopic assessment were did utilizing ATITM Mattson Infinity series, Bench top 961 controlled by Win First™ V2.01 software. Kinematic viscosity assessments were achieved utilizing Analis p-121 viscosity bath, Belgium. pH assessments were achieved utilizing InoLab, pH 720 WTW model, Germany. Copper strips agreeing to ASTM D 665.

2.3 Synthesis

2.3.1 Glycolysis of oil

Used glycolyzing agent like polyethylene glycol to get glycolized oil without using any catalyst according to the procedures of Belluco [34]. Polyethylene glycol-600 (68.5 g) and Sunflower oil (50 g) were burdened in 500 mL flask and heated. The temperature was elevated up slowly (6 °C each minute) and secure at 240 °C designed for 3 h [35]. At that time, the glycolysis of oil was permitted to cool at 25°C and the intermediate was filtered to eliminate the un-reactants. The obtained glycolized oil was designated as J600, S600 and C600.

2.3.2 Formulation of metal cutting fluids

The prepared added substances (2 mL) were utilized as emulsifying agent in the preparation of the metal cutting then conformation: 91 mL of distilled water, 5 mL from ecofriendly oils (Sunflower, Castor and Jatropha), and 2 g of co surfactant like Tween-20. The mix was mixed in great speed mixer (4000 rpm) to 20 minutes at 25 °C.

2.4 Assessment of Metal cutting Fluids Formulas

2.4.1 Stability of Emulsion

It defines the constancy of the metal cutting fluids preparations and their capability to be identical through store, carriage and usage [36]. The metal cutting fluid preparations which molded by presence

of the created emulsifiers were to be found in progressed cylinders at 25 °C and the attendance of oil cover in every cylinder was checked through 14 days in term of oil layer volume in mL. The emulsion constancy (%) was calculated in percent giving to the next calculation: **Emulsion stability %**

$$= \left(1 - \frac{\text{volume of oil separated}}{\text{total volume of oil in emulsion}}\right) \times 100 \quad (1)$$

2.4.2 Kinematic Viscosity at 40 oC and 100 oC

It defines the viscosity of the metal cutting fluid formulations at 40 °C which is appropriate for metal working at low temperatures of bending and twisting [37]. The amounts were did by Ubbelohde suspended level viscometer by a capillary diameter of 0.3 mm for amounts at 40 °C.

2.4.3 Anticorrosion Assessment

The maintenance of the metal through the handing out in the attendance of the metal working fluid preparations was confirmed by copper strip test rendering to the standard method [37]. A copper strip was kept in the changed communicated metal working preparations (300 mL) at 25 °C in three repeats for 24 h and the test strip is experiential for marks of erosion and the degree of this erosion. Erosion rating was measured in a gage from 0 to 10. No erosion was 10 grade and totally rusted was 0 grade.

2.4.4 Specific Gravity

It defines the workability of the metal working fluid formulation during the processing of metal fabrics. The assessments were did by (specific gravity flask) of 25 mL. An unfilled flask was weighted exactly, and after that it was occupied with the metal working fluid preparation, and weighted. Assessment was repetitive three times at 25 °C, and middling was careful [38]. Variation in weight was used to evaluate specific gravities of metal working fluids giving to next calculation: **Sp. Gr.**

$$= \frac{\text{weight of the filled flask} - \text{weight of the empty flask}}{\text{volume of the flask}} \quad (2)$$

2.4.5 Surface tension

It defines exterior dispersion of the metal cutting fluids preparations on metal surface in term of surface tension value. Surface tension data (γ) of dissimilar preparations were assessment by Du-Noüy tensiometer (Krüss type K6) (Hamburg, Germany). The tensiometer was standardized by deionized water at 25 °C. The surface tension assessment were occupied after that 10 min. of pouring the solution in the measuring cup to confirm the equilibrium [39].

2.4.6 Interfacial Tension Assessment (IFT)

The IFT was assessed among the surfactant solutions and cooking oil. The interfacial tension was measured by Du-Noüy tensiometer (Krüss type K6) (Hamburg, Germany).

2.4.7 pH values

It defines the alkalinity or acidity of the metal working cutting fluids preparations and their propensity to reason erosion for metal surface. The values of pH were reported using a pH meter for the dissimilar expressed metal working cutting fluids at 25 °C after 1 day of preparation.

2.4.8 GPC molecular weight

We measured molecular weight be waters 515/2410 Gel Permeation Chromatograph (GPC, Waters, America)

3. RESULTS AND DISCUSSION

3.1 Structure

Chemically Structure of the glycolized Oil (J600, S600 and C600) presented the next absorption bands: 2870 and 2923 cm^{-1} correspond to stretching of C-H groups of repeated ethylene glycol units; an absorption band seemed at 1106 cm^{-1} corresponds to stretching of C-O ether group; an absorption band at 1734 cm^{-1} which are corresponding to the carbonyl group (C=O) of esters; 3200-3700 cm^{-1} placed at 3396 cm^{-1} corresponds to stretching of O-H group in Fig. 3. [40, 41].

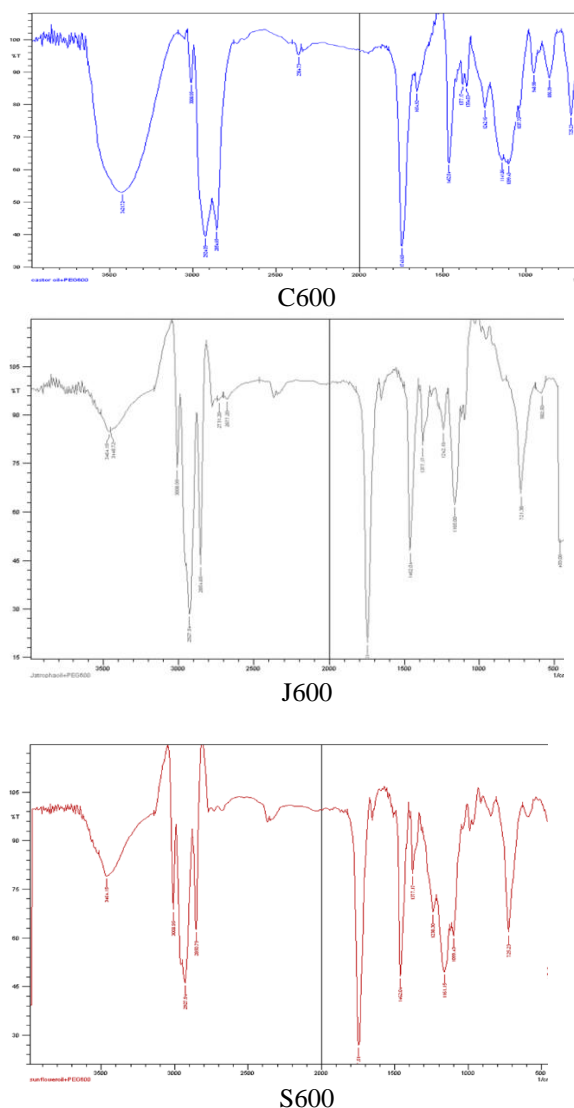


Fig. 3. FTIR of the glycolized oils (C600, J600 and S600)

3.2 Assessment of the formulated Preparations Erosion Inhibition

The capability to deliver erosion defense is significant for metal cutting fluids. Emulsion of Oil with water existence of prepared added substances assessed for erosion creation on copper strips. (Table 1) represents the consequences of anti-corrosion experiment before and after prepared added substances to the preparation after 1 and 10 days of involvement. The rust is shaped on metallic external surface through its preparing because its contact by aquatic and oxygen. Some character of formulated preparations is avoiding the rust creation on the metallic external through metal handing out [35]. The source of anti-corrosion formation in the existence of the prepared formulations is the existence of two

active parts in the chemical structure of the prepared added substances. Firstly, the alkyl moieties of oleic, linoleic or fatty acid mixture obtained from oil hydrolysis. Fatty acids were described by way of effective added substances for erosion avoidance in prepared formulations [42]. Unsaturated fatty acids containing maleic, ricinoleic, linoleic and oleic acids were combined in preparations as anti-corrosion added substances and displayed brilliant anti-corrosion test effects in existence copper and iron metals [42]. Secondly, the chains of polyethylene glycol in prepared added substances, that growths adsorption of added substances on the metal external surface. That protects the metal external surface from eroding substances [43]. The gotten anti-corrosion experiment effects recorded in Table 1 display two performances.

Afterward one day involvement in the metal working, copper external surface displayed no erosion result on the surface; 10 unit on anti-corrosion scale. The properties of anti-corrosion afterward one day

involvement display great protective inclination of the designed emulsion. Afterward ten day involvement of copper strips in the prepared formulations, the anti-corrosion measure was extended amid 8 and 9. The results display great antirust effectiveness of the various preparations. The adapted preparations have hydroxyl and alkyl chains that can be in control for rust prevention [44]. These consequences are in decent contract with the consequences gotten for copper metal in interaction with various partly hydrolyzed castor oil, Coconut oil, and sunflower oil [45]. The gotten prevention efficacy was at the all-out at 8 days, and then the erosion crops twitch to procedure. In the created added substances, the emulsions deliberate displayed exceptional anti-corrosion possessions after 10 days. It can conclude that this prepared formulations has good ability to inhibit the corrosion as in Fig.4. and Fig.5.

Table 1: Tribological possessions of the prepared metal working in attendance of prepared added substances.

Oil phase	Additive	Surface tension, mN/m	Specific gravity, g/mL	Viscosity @40 °C, cSt	Emulsion stability, day	pH	Anticorrosion test *	
							1 day	10 day
Jatropha oil	J600	45	1	89.6	30	5.5	10	8
	S600	45	1	87.0	26	6.4	10	8
	C600	44	1	92.0	28	6.1	10	8
Sunflower oil	J600	45	1	89.0	29	5.0	10	9
	S600	45	1	87.0	29	6.4	10	9
	C600	44	1	95.2	30	6.5	10	9
Castor Oil	J600	45	1	94.0	30	5.8	10	8
	S600	44	1	92.0	29	7.0	10	9
	C600	42	1	98.0	30	6.5	10	9

* Antirust test result after 1 day in absence of added substances was 5; and it was 2 after 10 day under experiment conditions.



Fig.4. copper strips immersed in Metal cutting fluids.

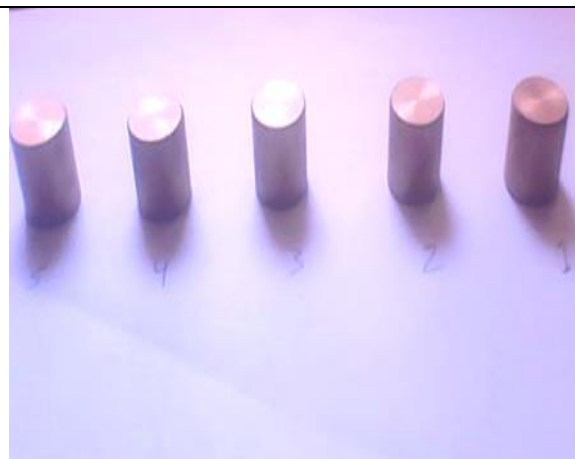


Fig.5. Copper strips after removed from metal cutting fluids.

Kinematic viscosity

Viscosity is a significant possession with admiration to fluid act and preservation. Lower viscosity fluids permit gravel and grime to relax out of suspension. Elimination of these contaminants recovers the excellence of the fluid recirculating over the machining system. This can influence produce excellence, fluid lifetime and machine workshop output. Kinematic viscosity represents the viscosity of the prepared formulations used at the metal surface. Viscous prepared formulations are promising in the machining procedures. The great viscosity of vegetable oils offers prepared formulations an oily feature and decent lubricating possessions. At sure viscosity, the rise will decrease the efficacy of the prepared formulations due to the damage of fluidity and so the lubricity influence of the fluid decreases.

The kinematic viscosity of the prepared formulations be contingent on two issues as can be understood as of the records scheduled in Table 1. Firstly, the kind of oil utilized in making the metal working fluid preparation. Oil possess higher viscosity produces higher viscosity preparation. In case of preparations have castor oil (as oil phase); assessments of kinematic viscosities are extending between 92 cSt and 98 cSt at 40 oC, which are the highest values. Although in circumstance of jatropha oil and sunflower oil (as oil phase), the gotten viscosities are ranging between 87 cSt and the maximum at 98 cSt at 40 oC. That can be credited to the comparative little viscosities of sunflower and jatropha related to castor. Secondly, kind of added substances (esters). In the attendance of S600 and J600 added substances, the viscosities of the preparations were the all-out. Though the preparations contain C600 have lesser viscosities.

Kinematic viscosities at 40 °C of Sunflower, Jatropha and castor oils are: 35 cSt [46], 35.98 cSt [47], and 232 cSt [48], correspondingly. kinematic viscosity of prepared metal cutting fluid contains sunflower oil was ranged between 92-98, while in the existence of sunflower oil was 87-92, and 89-94 in the existence of jatropha oil. Comparing the kinematic viscosities of the tested modified formulations having dissimilar vegetable oils combined by partly hydrolyzed vegetable oils [48-50] presented moderately great viscosity of the previous than the later. That presented the in height efficacy of the set modified formulation in the attendance the produced added substances.

Emulsion stability

A modified preparations is just a mixture of oil and water as emulsion. The constancy of that emulsion is a main marvel which estimated the applicable of the

metal fabrication in metal handing out [51]. The emulsification power defines the constancy of the modified preparations afterward sure time. Lessening the emulsion constancy for formulated leads to separating oil from water phases. Commonly, prepared formulations with produced added presented steady suspensions for 30 days,(Table 1). Numerous researches displayed that suspension constancies of the cutting fluids are diverse dependent on emulsifiers utilized. Sulfonated vegetable oils as emulsifiers showed 12 day constancy [52]; although epoxidized soybean oil by organo sulfur phosphorus displayed mild emulsion constancy in existence of soybean oil at 18 days [53]. Produced compounds, S-[2-(acetamido)thiazol-1-yl]dialkyl dithiocarbamate, as added substances in rapeseed oil were assessed [54] and displayed comparatively in height emulsion constancy at 40 days.

Studying the records in Table 1 shown that the constancy of designed emulsions count on mostly on the oil kind and fatty acid remainder related to polyethylene glycol. In J600, the constancies of emulsions made from jatropha and castor were relatively great related to emulsion made from water and sunflower. Castor and jatropha have greater proportion of oleic acid in their composition than sunflower. The oleic acid plenty in sunflower oil is abundant lesser than castor and jatropha oils [42]. Hereafter, homogeneity of emulsifier by sunflower oil is actual little. By way of a consequence, the gotten emulsion is very weak.

From another angle, S600 derivatives displayed the least emulsification propensity to the dissimilar oils. Because to two issues: chemical configurations of dissimilar oils (low linoleic acid meaning), and low solubility of emulsifiers in the aqueous phase. As of emulsification propensity measurements of prepared emulsifiers, it may be decided that emulsifiers of oils in prepared formulations are definite chemicals, and their constancy be determined by on their homogeneity with the utilized oil.




Emulsifiers	C600	J600	S600
glycolized products (J600, S600 and C600)			



Fig.6. Emulsion stability of formulated metal cutting fluids

Surface tension

Prepared formulations are acting their greasing act attributable to delivery of oil among the metal external surface and manufacturing tools [54], [55]. Delivery of formulations on metal external surface count on connection among metal and liquid, The additive increase the dispersion of formulation on surface of metal by decreasing surface tension. The prepared metal working by prepared added substances act as emulsifiers are extended amid 42 and 45 mN/m. The prepared added substances have surface activity subsequently decrease surface tension of the formulations [55]. The surface active characters of the synthesized additives were got from hydrophilic and hydrophobic parts in their molecules [56]. The presence of polyethylene glycols in the dissimilar added substances acts as hydrophilic part. While, hydrophobic is possessed to the existence of fatty acids connected to their chemical configurations [57]. Existence of two kinds of parts growths the surface activity for added substances and reductions their surface tension to lesser numbers [58]. Surface tension numbers (Table 1) are deemed modest to lesser associated by numerous cutting fluids preparations holding: polysorbitan stearyl ester (42.5 mN/m) [35]. Commercial cutting fluids having dissimilar fatty acids providing moderately developed surface tension numbers reached among 39 and 58 mN/m [59].

Interfacial Tension Measurements (IFT)

The IFT was measured amid the surface active agents solutions and cooking oil. The interfacial tension was measured using (Krüss type K6) (Hamburg, Germany) [60]. Interfacial tension values of prepared surfactants are ranged between 5 and 9 due to compatibility of surfactants with cooking oil and by increasing double bond of free acids in glycolized oil from sunflower then *Jatropha* to Castor oil.

Table 2: interfacial tension glycolized acid.

Oil phase	Emulsifiers	IFT(mN/M)
Cooking oil	S600	9
Cooking oil	J600	8
Cooking oil	C600	5

pH values

Metal handling intermediate is Acidic or alkaline for a heavy-duty reason for metal erosion. Keeping the intermediate at moderate pH defends metal versus erosion particularly aluminium and copper [61]. The pH numbers of the additives are extending among 5 as well as 7.0 after 7 days, Table 1. These number don't variation by period, representative the chemical constancy of the unlike preparations. The additives are esters made amid dissimilar fatty acids and glycolized polyurethane. Hydrolysis of the ester additives as cutting fluids preparations may happen. The danger of esters hydrolysis is create in basic intermediate and too in somewhat acid form intermediate.

GPC molecular weight

we can notice that molecular weights for formulations C600, C1000, C1500 are 820, 1294, 1816 respectively we can notice that by increase molecular weight of polyethylene glycol molecular weight of formulation increase.

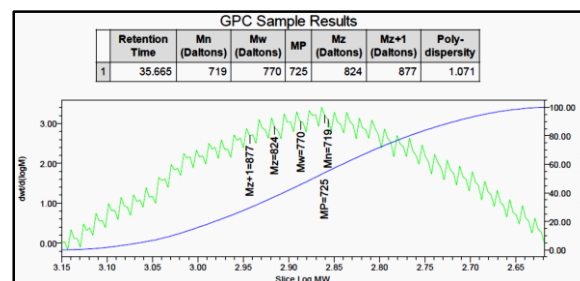


Figure 3: Molecular weight of C600

Conclusions

From these study and it results many of opinions can be take out:

- * The anti-corrosion possessions of the designed suspensions is very great, and touched to 30 days, which is relatively great efficacy.

- * The prepared added substances possess great emulsification control and yield steady oil in water suspensions, linked to the trade and newly produced nonionic polyethylene glycol, sorbitan and glycerol based emulsifying agents.

- * Acidity of suspensions designed is in a satisfactory range of 6 to 7.6.

* The dispersion influence of the suspensions designed through the produced added substances is great relatively to the nonionic added substances.

* The efficacies of the preparations designed by the prepared added substances are relatively greater than the preparations had nonionic surface active agent and adapted oils.

* The emulsifying agent are definite to oil utilized in metal cutting preparation and be able to be synthesized beginning hydrolyzed fatty acids of oil combined in preparation.

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