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Analytical assessment of steel cord drawing lubricant with and without triple mixed-additive addition

Farinaz Shahimi*

Saba Tire Cord Manufacturing Complex, Zanjan, P.O. Box: 45195/441, Iran

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ABSTRACT

The lubrication is one of the most significant operations in the process of steel cord drawing which affects the final product quality. In this study, the effect of utilizing triple mixed additive (pH stabilizer, antifoam, and biocide) on the variety analytical parameters of lubrication medium such as pH, Fe and Cu concentrations, conductivity, fat content and bacteria contamination were investigated. The used lubricant was analyzed via different analytical methods in the presence and absence of triple-mixed additive over 30 days period. The results showed that the pH values of the additive-involved lubrication medium are changed in the lower ranges with more correlation than without additive medium. The Fe and Cu concentrations of the additive-contained lubricant are increased with a smaller slope over time. Consequently, the conductivity of the lubricant in the presence of triple-mixed additive is increased very gradually with low slope and high correlation which can be attributed to the synergistic effect of additive with lubricant ingredients in lubrication process. The fat content of additive-included lubrication medium is slightly higher than that of lubrication without additive. Moreover, the bacteria contamination in the presence of triple-mixed additive was very lower than the medium without any additive. The obtained results showed that the analytical characteristics of the lubrication medium were desirably affected by the triple-mixed additive.

Keywords: Steel cord; Lubricant; Drawing; Additive; Wire; Die.

1. INTRODUCTION

The operation of wire pulling in a die to diameter decreasing or shape changing is called wire drawing. Depending to their thickness, the products of this process is generally utilized in car tires, electrical cables, bolts or fasteners manufacturing. Due to the wire-die friction, the wire surface deteriorates over time. Therefore, the process is actually required to utilize an appropriate lubricant in the wire-die space to decrease the needed load and the surface quality degradation [1-3]. The efficacy of

*Corresponding author: farinazshahimi@gmail.com

wire drawing is affected by metal-die lubrication. The lubricant ingredients play vital role in the lubricating effectiveness for wire drawing. In the wire-die interface, the drawing power is affected by friction stress and temperature rises, consequently. Using appropriate lubricants causes to low friction, energy saving and decreasing production costs. The variety parameters such as material of die, drawing speed and lubricant ingredients affect the lubricating performance. Moreover, the useful life of dies strongly depends on anti-wear characteristics of wire [4-6]. So, it can be said that the drawing performance operation depends on three main factors: (i) the die length and angle (ii) the wire material characteristics, and (iii) the drawing speed and friction at the die-wire interface [7-12].

The objective of this investigation is to study the effectiveness of pH stabilizer, antifoam, and biocide agents as a triple-mixed additive on the wire drawing process of steel cord. The used mixed-additive is supposed to be less in cost than the used general lubricant's additives. The different parameters such as pH, Cu and Fe concentrations, fat content, conductivity and bacteria contamination of lubricant emulsion are compared with and without using mixed-additive in a period of 30 days.

2. MATERIALS AND METHODS

The studies were performed via center lath machine with a motor power of 10 kW. The drum is located on the jaws of the center lath with rotational speed 1500 rpm. The raw material which is utilized in this work was steel cord with initial diameter 1.75 mm. The annealing was performed at temperature 40 °C for 10 minutes. After turning on the drum and mounting by screw bolt, the was passed through the lubricant medium. The final diameter was measured as of 0.3 mm. The utilized analytical instruments were pH meter InoLab WTW 7310, conductometer InoLab WTW series 1, and Spectrophotometer Hach dr 4000U.

3. RESULTS AND DISCUSSION

3.1. Effect of triple mixed-additive on pH of drawing lubrication medium

pH degree is the most appropriate factor to determine the degree of acidity or alkalinity of the drawing emulsion. According to the definition, pH=7 corresponds to neutral solutions, values between 0 and 7 for acidic environments and pH between 7 and 14 for alkaline environments. For drawing lubricants, the best pH range is between 8 and 9.5.

The drawing emulsions are designed in such a way that they always work in an alkaline environment. Due to the penetration of air into the emulsion and the reaction between the oil and the oxygen in the air, this amount always tends to decrease. Therefore, controlling the pH of drawing emulsion is very important. If the pH level of the drawing emulsion is lower than 8, the corrosion possibility of different parts of the device increases, which is caused by the creation of electrolyte between steel and copper. This will cause damage to the polished surface of the tension sheets. Corrosion in this environment may also be caused by the passage of creeping currents caused by ground connection of some parts. Therefore, it is strongly recommended to control the pH level in the following cases:

(i) In the heavy rod tensioning machines whose wire is washed by acid. Due to the presence of acid on these wires and its penetration into the emulsion, pH value decreases.

(ii) Stretching machines, some of which use special grease for lubrication. In this type of equipment, the pH level tends to increase. When the volume of wire that is thinned by the device is very large

compared to the volume of circulating emulsion, the pH tends to increase. In these cases, it is recommended to increase the circulating emulsion volume or increase the drawing oil concentration instead of correcting the pH value with acidic substances [13-15].

The effect of the mixed-additive addition on the pH of drawing lubricant is represented in Figure 1. The pH of the lubrication medium was monitored with and without addition of mixed-additive for a 30 days period. The pH values of lubricant were changed in the range of 8.38-9.20 and 8.74-9.50 with and without additive addition. The pH values in both environments tend to increase over time. It can be seen that the pH values in the presence of additive were changed slightly with more correlation (R^2= 0.769) in comparison with additive absence (R^2= 0.5387). Obviously, using mixed-additive in the lubrication medium could adjust pH variation in the lower ranges. It can be concluded that the addition of triple mixed-additive in the lubricant improves the lubrication operation quality by adjusting the pH of lubrication medium.

In order to better evaluate of pH changes in both lubrication mediums, normality test, outlier test and F test also were performed on the obtained pH values (Fig. 2). According to the normality test results, the distribution of pH data in the WA and WOA mediums were pass and fail, respectively (Fig. 2a). The outlier test results show that there is no any outlier pH data in both WA and WOA mediums (Fig. 2b). Due to the P value $\geq$ 0.05, it can be said that the data distribution is acceptable (Fig. 2c).

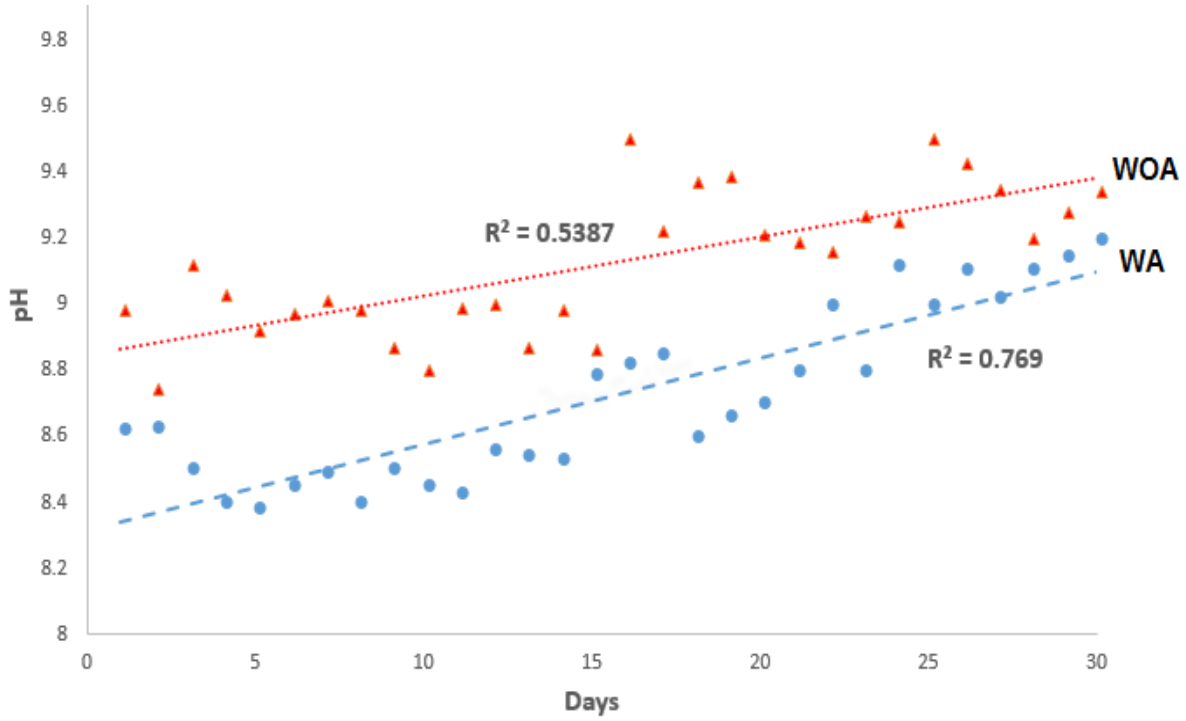
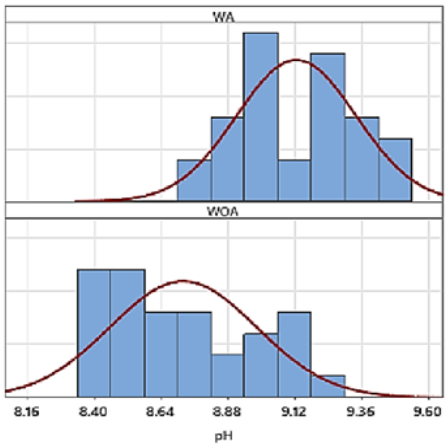
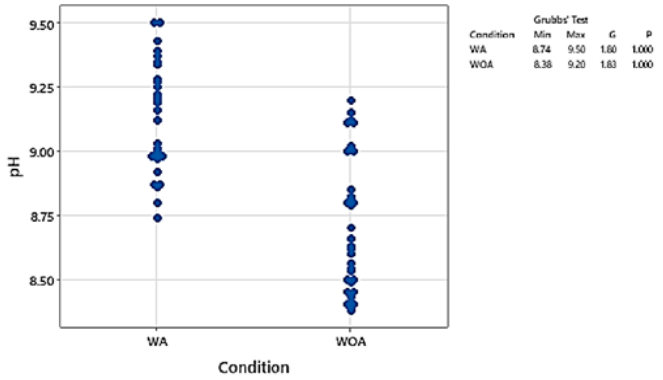


Fig. 1. pH values alterations of the lubrication medium with (abbreviated as WA) and without triple mixed-additive (abbreviated as WOA) during 30 days period time.





(b)

Group	N	Mean	95% CI	StDev	95% CI	Min	Median	Max	Normality Test P	Decision
WA	30	9.126	(9.0461, 9.2059)	0.21405	(0.1705, 0.2878)	8.74	9.14	9.5	0.274	Pass
WOA	30	8.7203	(8.6222, 8.8184)	0.26271	(0.2092, 0.3532)	8.38	8.645	9.2	0.018	Fail

(a)

Method

σ₁: standard deviation of pH when Condition = WA
σ₂: standard deviation of pH when Condition = WOA
Ratio: σ₁/σ₂
F method was used. This method is accurate for normal data only.

Descriptive Statistics

Condition	N	StDev	Variance	95% CI for σ
WA	30	0.263	0.069	(0.209, 0.353)
WOA	30	0.214	0.046	(0.170, 0.288)

Ratio of Standard Deviations

Estimated Ratio	95% CI for Ratio using F
1.22733	(0.847, 1.779)

Test

Null hypothesis	H□: σ₁ / σ₂ = 1
Alternative hypothesis	H□: σ₁ / σ₂ ≠ 1
Significance level	α = 0.05

Method	Test Statistic	DF1	DF2	P-Value
F	1.51	29	29	0.276

(c)

Fig. 2. Performed normality test (a), outlier test (b) and F test (c) on the obtained pH values. The lubrication medium with triple mixed-additive is abbreviated as WA and without triple mixed-additive is abbreviated as WOA).

3.2. Effect of triple mixed-additive on Fe concentration of drawing lubrication medium

The Fe concentration of the lubrication medium increases overt time due to the steel cord abrasion in the wire-die interface [16]. The effect of triple mixed-additive on the Fe concentration of lubrication medium in the 30 days period is demonstrated in Figure 3. The Fe concentration of the lubrication medium was changed in the range of 2.2-388 mgL^{-1} and 1.1-812 mgL^{-1} with and without addition of triple-mixed additive, respectively. It can be seen that the Fe concentration increment in the lubrication medium is performed in a

lower slope in the presence of triple mixed-additive in comparison with the lubrication medium without any additives. It can be attributed to the synergistic effect between mixed-additive and lubricant ingredients for lubricating the wire-die interface which is caused to improve drawing process. R^2 values for the obtained data with and without additive were obtained 0.9435 and 0.9422 respectively which demonstrate that the Fe concentration values have very good correlations in both studied mediums.

3.3. Effect of triple mixed-additive on Cu concentration of drawing lubrication medium

Similar to the previous section, the Cu concentration of the lubrication medium increases due to the abrasion of the brass-coated steel cord in the wire-die interface in the drawing process. Figure 4 shows the Cu concentration changes of lubricant in the presence and absence of triple-mixed additive. The Cu concentration has altered in the range of 3.1-796 mgL^{-1} and 1.2-1928 $mgL^{-}1$ with and without addition of additive to the lubrication medium, respectively. Clearly, utilizing the triple mixed-additive not only decreases the domain of Cu concentrations over time, but also causes to lower slope of increasing Cu concentration in the 30 days period.

3.4. Effect of triple mixed-additive on the conductivity of drawing lubrication medium

The conductivity of the lubrication medium tends to increase over time due to the raising Fe, Cu and Zn concentration because of wire abrasion in the wire-die interface and entering the produced splinters into the lubrication medium. The effect of the triple-mixed additive addition in the lubricant mix on the conductivity of the lubrication medium is shown in Figure 5. The conductivity of lubrication medium is increased from 4 µS/cm to 7.6 µS/cm and from 4.01 µS/cm to 9.5 µS/cm in the presence and absence of mixed-additive, respectively. It can be seen that the conductivity increment has been happen in a lower slope in the presence of additive. The reason of this effect may be due to the lower production of Fe, Cu and Zn splinters in the triple mixed-additive included medium which reduces the abrasion amount of steel-cord in the wire-die interface. Furthermore, the conductivity of the lubricant is slightly and regularly increased with mixed-additive addition which is caused to very good R^2 value 0.9778 compared with R^2 value 0.7611 without additive addition.

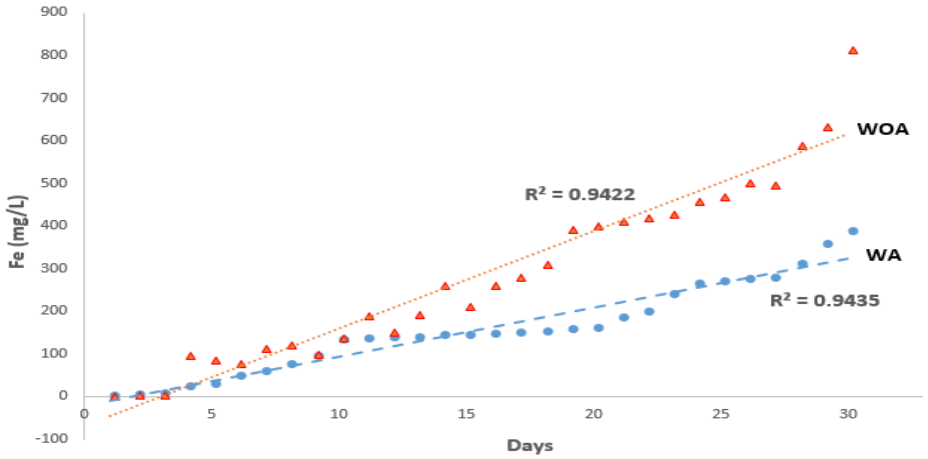


Fig. 3. Fe concentration values of the lubrication medium with (abbreviated as WA) and without triple mixed-additive (abbreviated as WOA) during 30 days period time.

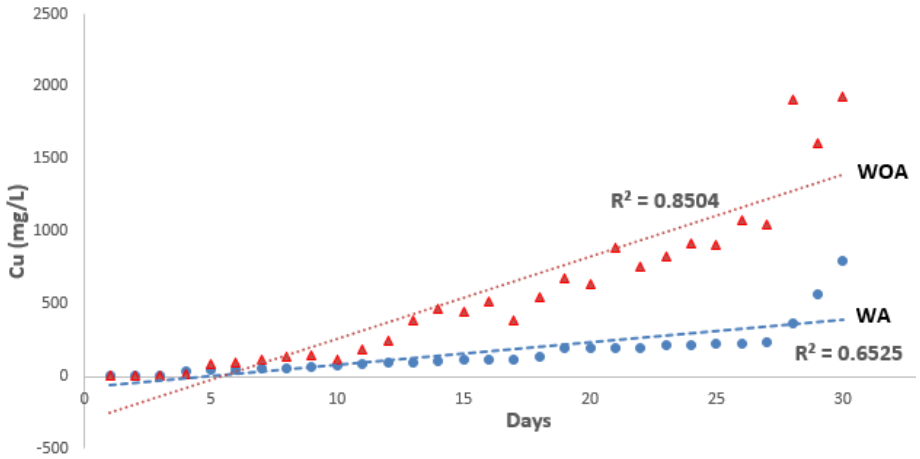


Fig. 4. Cu concentration values of the lubrication medium with (abbreviated as WA) and without triple mixed-additive (abbreviated as WOA) during 30 days period time.

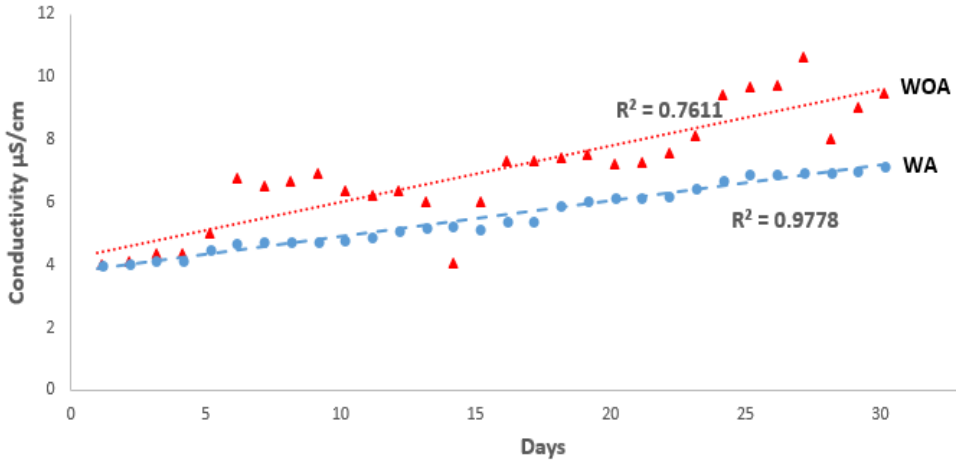


Fig. 5. Conductivity of the lubrication medium with (abbreviated as WA) and without triple mixed-additive (abbreviated as WOA) during 30 days period time.

3.5. Effect of triple mixed-additive on the fat content of drawing lubrication medium

Emulsion fat changes under various factors. The continuous release of the wire, which is always covered with some fat, or the settling of copper particles separated from the wire during the drawing process, which is covered by a layer of fat, reduces the total amount of fat in the emulsion. At the same time, the constant evaporation of water and its insufficient compensation also cause an increase in fat. Based on this fact, the amount of fat in the stretching emulsion should be controlled and recorded at regular intervals. This amount is usually declared by the manufacturer, but it should be in the following range:

- Heavy drawing machine 10%-17%.
- Medium drawing machine 4%-8%.
- Fine drawing machine 2% to 4%.
- Super fine drawing machine 1% to 2%.
- Annealer water 0.5% to 1.5%.

Undoubtedly, the above values will depend on the quality of the wire, the type of machine and its linear speed. For example, the presence of too much fat causes it to deposit on the output wire and cause problems in the continuation of the process. At the same time, high fat causes a decrease in the pH level of the emulsion

and dirt and sometimes clogs the iron hole. It should be noted that cooling in high fat emulsions is not done well and this leads to the short life of die. Too little fat also causes excessive tearing of the wire and rapid corrosion of the iron and tension flakes.

The effect of addition of triple mixed-additive in the lubricant on the fat content of lubrication medium is represented in Figure 6. The fat content of the lubrication medium is changed between 11%-16.5% and between 6%-16.5% in the presence and absence of additive, respectively. It can be seen that the fat content increases in both medium; however, it raised gradually with low fluctuations in the presence of additive. The increase of the fat content may be due to the water evaporation of the lubrication medium.

3.6. Effect of triple mixed-additive on the bacteria contamination of drawing lubrication medium

Bacterial contamination of big circulating oil systems in steam turbines, paper machines and similar systems is a growing problem. Drawing lubricants generally contain already some bactericides, but due to inappropriate working conditions or a contaminated water supply, the growth of bacteria can be turned into a very critical problem [17]. As mentioned earlier, one part of the used triple mixed-additive was biocide. The bacteria contamination of the lubricant medium was monitored at initial and final of 30 days period using appropriate test kits. (Fig. 7). Obviously, using triple mixed additive addition, the bacteria growth in the lubrication medium has been significantly decreased. Therefore, it can be concluded that the utilized mixed-additive shows excellent efficiency as an antibacterial agent.

CONCLUSION

It has been demonstrated that the lubrication medium of the wire drawing machines and its ingredients and analytical characteristics affect the quality of final product, energy consuming, overall yield, waste value, etc. The results of this study showed that the utilizing of triple mixed-additive in the lubrication medium causes an adjustment and proper regulation of pH values, a reduction in wire-die abrasion, subsequent decrease in slope of Fe and Cu production and medium conductivity. The fat content of medium increases slightly with lower fluctuations in additive-involved medium. Furthermore, the bacteria growth in the triple mixed-additive included medium decreases considerably. All the obtained results proved the efficiency of used additive in the lubrication medium of steel cord drawing. These investigation results could be utilized in the steel cord drawing industries for performing of novel technologies in this area.

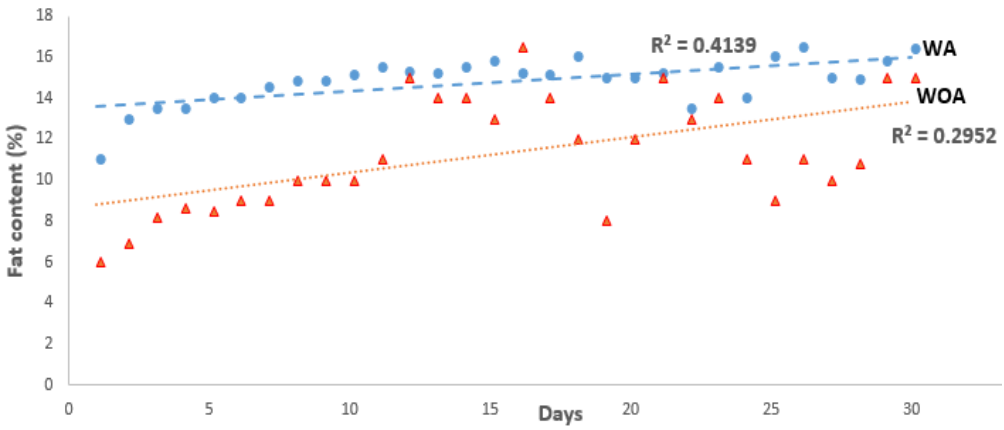
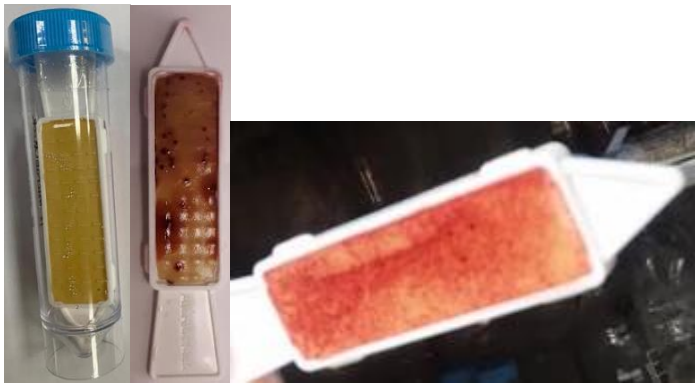


Fig. 6. Fat content of the lubrication medium with (abbreviated as WA) and without triple mixed-additive (abbreviated as WOA) during 30 days period time.



(a) **(b)** **(c)**

Fig. 7. Bacterial contamination test kit at its pristine form (a), after 30 days in lubrication medium with triple mixed-additive (abbreviated as WA) (b), and after 30 days in lubrication medium without triple mixed-additive (abbreviated as WOA) during 30 days period time.

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ارزیابی تجزیه‌ای روان‌کننده کشش استیل کورد با و بدون حضور مخلوط افزودنی سه‌گانه

فریناز شهیمی*

مجتمع تولیدی نخ تایر صبا، زنجان، ایران

چکیده

روانکاری یکی از عملیات‌های بسیار مهم در فرآیند کشش استیل کورد می‌باشد که بر کیفیت محصول نهایی تاثیر می‌گذارد. این مطالعه تاثیر استفاده از یک افزودنی سه‌جزئی (تثبیت کننده pH، ضد کف و بایوساید) روی پارامترهای تجزیه‌ای مختلف محیط روان‌سازی مانند pH، غلظت‌های آهن و مس، هدایت، محتوی چربی و آلودگی باکتریایی مورد مطالعه قرار گرفت. روانساز مورد استفاده توسط چندین روش تجزیه‌ای متفاوت در حضور و غیاب افزودنی سه جزئی در طول یک دوره ۳۰ روزه مورد آنالیز قرار گرفت. نتایج نشان دادند که مقادیر pH محیط روانساز شامل افزودنی در گستره کمتر و همبستگی بیشتر نسبت به محیط بدون افزودنی تغییر یافتند. غلظت های آهن و مس روانساز حاوی افزودنی با یک شیب کوچکتر در طول زمان افزایش پیدا کردند. در نتیجه هدایت روانساز در حضور افزودنی سه جزئی بسیار تدریجی با شیب اندک و همبستگی بیشتر افزایش یافت، که آن را می‌توان به اثر هم افزایی افزودنی با اجزای تشکیل دهنده روانساز در طول فرآیند روان‌کنندگی نسبت داد. محتوای چربی محیط روان کننده حاوی افزودنی اندکی بیشتر از محیط بدون افزودنی بود. علاوه بر این آلودگی باکتریایی در حضور افزودنی سه جزئی بسیار کمتر از محیط بدون هیچ گونه افزودنی به دست آمد. نتایج بدست آمده نشان دادند که ویژگی‌های تجزیه‌ای محیط روان‌ساز به طور مطلوب توسط افزودنی سه‌جزئی تحت تاثیر قرار می‌گیرد.

کلید واژه‌ها: استیل کورد؛ روان‌کننده؛ کشش؛ افزودنی؛ سیم؛ قالب

* مسئول مکاتبات: farinazshahimi@gmail.com