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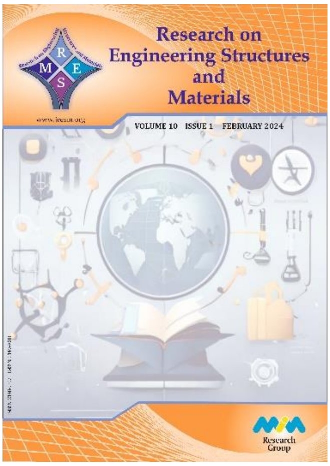

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Research Article

The effect of age and wear on the mechanical performance of HDPE 80 polyethylene pipes

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Abstract

In this work, we studied the influence of accelerated aging in an aggressive environment of high-density polyethylene (HDPE 80) used for pipeline applications to distribute gas. Accelerated aging by ultraviolet irradiation of the wavelength lamps (λ = 365nm) for 240 hours at a temperature of 35°C exposed samples to solar radiation on the sand in southern Algeria for 12 months. The samples were subjected to weathering at -10 °C and 25°C for four different durations. To assess the weight loss capacity of semi-crystalline polymer behavior (HDPE 80) Under accelerated aging conditions, aging is carried out mainly according to three referenced methods: ISO 105 B02/B04, DIN 75202, and SAE J 1885. The Taguchi method and regression analysis were used. Several experiments were conducted on a vertical milling machine using a multi-factor L16 (4^1*2^3) orthogonal mixed matrix. An analysis of variance (ANOVA) was used to determine the effects of treatment: corrosion, weight loss, and loss of thickness. The parameters are influenced by the sandpaper's grain diameter, cutting speed, and compressive strength continuity over two hours, with each trial lasting 15 minutes. Using S/N ratios, optimal control factors were determined to minimize lost weight (P) and thickness loss (ΔL) due to abrasion of HDPE polyethylene pipes 80. At A3, B2, C2, D2 (i.e. degradation mode = UV, rotation speed = 355 rpm, load = 9.3 N, abrasive paper = 10.3 degrees) and A3, B1, C2, D1 (i.e. degradation mode = UV, rotation speed = 180 rpm, load = 4.65 N, and abrasive paper = 18.3 degrees), ideal conditions for weight and thickness loss were observed.

1. Introduction

In sliding pairs against metals and other materials, polymers are commonly utilized, the phenomenon of absorption and diffusion under constant conditions and at various stages is one factor that affects the aging of polyethylene (HDPE); this phenomenon was the subject of numerous investigations using samples made of equations for stress. Fragments of bottles made of HDPE material were also demonstrated using mechanical tensile tests, crimps, Using ABAQUS software, a study of the aging phenomena of high-density polymers was conducted, The findings revealed a pattern that lowers compressive strength [1]. As a result of interactions between the various species in the mixtures during decomposition, the degradation of HDPE 80 polymer material is aging. It can greatly alter the progressive degradation behavior of the components, which could result in deterioration. Additionally, compared to the natural components, the reactions speed up the pace of disintegration, making it more challenging to recover the required qualities of HDPE 80 polyethylene through treatment and causing severe damages, such as the bursting of HDPE 80

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polyethylene natural gas pipelines [2]. In manufacturing and in the channels used to transport various soft liquids like water, gas, and oil, HDPE 80 polymer material is one of the plastic materials that cannot be done without. Under normal circumstances, corrosion is easily handled at a reasonable cost [3 and 4]. The results focused on the fatigue behavior of a group of thermoplastic polymers mixed with composite materials. They showed that the Walker bond was the best, as it fits the Smith-Watson-Topper link with the experimental data using SN curves through which the Baskin equation and correction [5]. Using Taguchi analysis and ANOVA, multiple correlations were performed using L18 (2*3*3) different effects (surface roughness, cutting tool wear, cutting speed, and feed). The results showed that plastics are significantly less resilient to premature aging, especially when friction and wear occur in different media, depending on how the sliding surface moves [6]. Results of the matrix (2*3*3) of the Taguchi method showed success in improving surface roughness and corrosion under the effect of cutting speed, suggesting that the aging of plastics by corrosion in some media may be associated with the roughness of contact surfaces and compression forces [7]. The improvement of the bending ability of CFRP sheets made of carbon fiber-reinforced polymer and its strengthening under the influence of RC beams may reach 100% compared to the control beam using the finite element method to develop a digital model for analysis. [8]. Reduces high abrasive wear loss and dry plastic deformation of Al-Si automotive alloys on a standard disc-mounted device by controlling the lubricating film used for a lower wear rate and coefficient of friction due to aging [9]. It was also observed after UV exposure to high-density polyethylene (HDPE) used in solar panels for periods of varying durations up to 1152 hours, as this material highlighted its resilience by maintaining its properties under sunlight with a slight change [10]. Some studies have dealt with the design of experiments for production engineering (DOE), manufacturing technology to improve metal cutting tools, and also touched on the use of contemporary methods in the design of experiments for production engineering and during a previous study, an inference of the amount of rainfall affecting grass growth rate was also obtained using DOE in statistical analysis. In the author's opinion, the user must learn the Design of Experience [DOE] method. [11 and 12]. Also, heat effects on the fatigue behavior of HDPE allow the calculation of average stress by creating a general fatigue model for this substance [13]. Plastic PET is an additive to improve hardness during exposure to different temperatures [14]. The polyamide material P66 high molecular mass is characterized by improving and enhancing its corrosion resistance on its steel counterpart, which occurs through friction between two bodies [15]. Adding nanofibers to an HDPE matrix in a specific proportion can also treat plastic deformation and increase wear resistance and toughness. This improves toughness during tensile and thermal friction wear [16]. When the substance used for tubes is damaged by the loss of fish from the diameter deficiency whale by up to 40%, you should improve and review [17]. Frictional wear was examined using nano-micro-lubrication tribology in relation to material surface wear, Wear gradually reduces as the material loses its surface properties due to contact with another surface during movement [18 and 19]. According to research results, the treatment of the friction phenomenon of HDPE polymers improves by adding TiN titan compounds, where the relationship between the specific corrosion rate of the added compounds is found [20]. The use of plastic in shopping bags and edibles increases the likelihood of environmental contamination and endangers the growth of wild and marine plants and animals [21]. A new model of mechanical properties degradation has been developed. The prepared model uses cumulative data for distribution functions to approximate experimental data by calculating factors that reduce mechanical properties after periodic exposure to plastics and composite fatigue [22]. The Gray Relation study was used to improve the corrosion study of multi-response carbon-carbide-filled epoxy composites under the influence of four factors [23]. Artificial neural networks were used to study the effect of the coefficient of friction and contact temperature on a 30% carbon fiber-reinforced polyetherketone compound. The effect of the coefficient of friction on weight loss was compared to the contact temperature factor, the coefficient of friction was mainly affected, and the thermal factor also significantly affected weight loss. [24]. In a previous study of sliding wear of polypropylene (PP) with steel on a dry body, the addition of CNT to PP affected the corrosion performance using a scanning electron microscope. We discussed the phenomenon of corrosion, i.e., the loss of surfaces' properties during contact [25]. A study was also conducted on the polymer material's friction wear method in hip prosthetic applications. The polymer material was tested under contact conditions, sliding speed, and constant pressure to obtain the best results [26]. The difference was explained in the manuscript by adding text in the last paragraph of the introduction as follows: The Taguchi method and regression analysis were used under several experiments on a vertical milling machine using an L16 (4^1*2^3) multi-factor orthogonal mixed matrix with the effect of wear on the natural and industrial ambient conditions used. This research also presents a new method to study the effect of various factors on the life of HDPE 80 polyethylene used in natural gas transportation channels, including exposure to sunlight, freezing, heating, and ultraviolet radiation, compared to the initial state of HDPE polyethylene. During this study of the phenomenon of artificial and natural aging and frictional wear of gas distribution pipes made of high-density polyethylene HDPE80, we used the L16 (4^1*2^3) array of the Taguchi array to determine the conditions for conducting experiments and to determine the influencing factors such as coarse paper grain size, rotational speed, and compressive strength, in addition to determining the time for each experiment to minimize weight loss and avoid scratches on the surface.

2. Experimental Section Experimental Method and Study Material

High-density polyethylene (HDPE 80), which is well-known for its thickness of 11.5 mm, inner diameter of 176 mm, and outer diameter of 200 mm, was used for natural gas pipelines in this investigation, as indicated in Tab. 1. The thermal properties and measurements of the examined pipes are listed here. Wear samples made of the high-density polyethylene HDPE80 material are displayed in (Fig.1). in the shape of a disk of 10 mm in diameter and 4 mm in thickness.

Table 1. Properties of test materials [27]

Materials	Code	Density	Elastics modulus	Elongation	Fracture energy
High Density Polyethylene	HDPE	0.952	276	700	126
Middle Density Polyethylene	MDPE	0.945	207	740	129
low-density polyethylene	LDPE	0.938	130	630	79
Polyethylene 100	PE100	0.962	260	740	137

Table 2. Experimental conditions for the abrasive wear tests

Load (N)	4.65 and 9.3
Rotation speed of disc (rpm)	180 and 355
Mean contact pressure (MPa)	59.24×10−3 and 118.47×10−3
Radius of wear track on disc (mm)	42
Testing time (min)	1–15
Sliding distance (m)	13.2 – 33.9
Abrasive paper (μm)	1000 and 2000 (18. 3 and 10.3)

With the crushing technique, wear between the polyethylene material and the surface of the abrasive paper causes a layer to be deposited on the surface. Some properties must be determined during and after the experiment, as shown in Table 2.

3. Tribological Features

A vertical milling machine used for pin and disc wear tests, as shown in the schematic diagram in (Fig.1) [28], of the wear test apparatus, as discussed in previous studies by Guermazi (2008), Liu and al (2006), in tensile and wear experiments on samples of a polymer material, the wear experiments were carried out at a laboratory temperature of 21 °C and using abrasive paper with grain sizes 1000 and 2000 (grain sizes 18.3 and 10.3 µm). It is installed on the milling machine table, as shown in the picture [29]. The rotational speed was given at two consecutive speeds (180 and 355) revolutions per minute for the friction device that holds the compressed pin with a force of (9.3 and 4.65) Newton under spring pressure so that the samples are weighed before and after each experiment for two hours, respectively, divided by a quarter of an hour for each measurement. Then, with a high-precision scale of 10^-4g, the abrasive paper is also changed for each trial, the amount of weight loss is calculated by the difference after each test, and the thickness is measured with a micrometer.

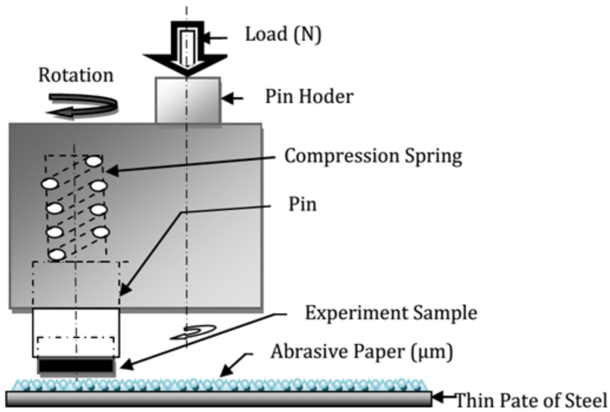


Fig.1. Schematic representation of the wear testing device

4. Accelerated Aging Procedure

The aging effect of the robust and diverse environment accelerates the behavior of semi-crystalline polymer (HDPE 80). The degradation behavior of the polymer material was analyzed by various methods and subjected to accelerated ultraviolet (UV) aging. Ultraviolet radiation decomposition of the lamps to wavelength (= 365 nm) in 240 hours at 35 °C, exposure to sand in southern Algeria for 12 months, and thermal aging in lousy weather at -10 °C and 25 °C for four different periods for three months for an entire year.

After the experiment, the weight (P) of the sample was determined with high precision (10-4 g) using an electronic balance (Eqn.1) while calculating the thickness loss (ΔL). A vernier caliper was used to correspond to the difference between the length value of the sample before and after the experiment (Eqn.2). The pressure value is kept constant using an elastic spring of a friction device.

$$P = P_n - P_{n-1} \tag{1}$$

P: weight loss value; Pn: Initial weight; Pn-1Weight After the test.

$$\Delta l = L_n - L_{n-1} \tag{2}$$

ΔL: elongation; Ln: the initial length; Ln-1: the length following the experiment.

5. Taguchi Method and Experimental Design

The Taguchi method is widely used in engineering analysis because it reduces the number of experiments with orthogonal matrices and the effects of uncontrollable factors. Moreover, it provides a scientific method for determining the weight loss during the wear of manufacturing materials [29]. By converting the quality analysis method into a signal-to-noise ratio (S/N) file, the Taguchi method is also used to calculate the empirical values of the various factors affecting the material used and the values available through the lowest loss, most effective. The best-used S/N ratio for each level [7] was used, and experiments were performed using Taguchi's method with a mixed orthogonal matrix. Table 3. Regression analysis on a vertical milling machine, and the L16 (4^1*2^3) multifactorial design Influence factors and their levels Table 4.

Table 3. Full factorial design with an orthogonal array of Taguchi L16(4^1*2^3)

N° of experiments	Factor (A)	Factor (B)	Factor (C)	Factor (D)
	(months*3)	(rpm)	(N)	(µm)
1	1	1	1	1
2	1	1	2	2
3	1	2	1	2
4	1	2	2	1
5	2	1	1	1
6	2	1	2	2
7	2	2	1	2
8	2	2	2	1
9	3	1	1	1
10	3	1	2	2
11	3	2	1	2
12	3	2	2	1
13	4	1	1	1
14	4	1	2	2
15	4	2	1	1
16	4	2	2	2

Table 4. Influence factors and their levels

Parameters	Symbol	Level 1	Level 2	Level 3	Level 4
Degradation modes (months)	A	3	6	9	12
Spindle speeds(rpm)	B	180	355	-	-
Load (N)	C	4.65	9.3	-	-
Abrasive paper (µm)	D	18. 3	10.3	-	-

The Taguchi technique calculates the deviation between theoretical and experimental values using a loss function. In addition, the signal-to-noise ratio (S/N) is calculated using this loss function (grams for weight loss and millimeters for thickness loss). The purpose of this study was to lessen the corrosion of the pipes under investigation since corrosion causes weight loss and surface scratches, both of which directly impact wear, particularly during the aging phases. As can be seen in (Eqn.3), the "Smaller is better" characteristic of lesser quality was employed (better minimize).

$$\eta = S/N_S = -10\log[\,{}^{1}\!/_{\eta}\sum_{i=1}^{\eta} y_i^2\,] \qquad (3)$$

(S/N): Signal-to-noise ratio

6. Evaluate and Analyze the Results of The Experiments

6.1. Signal-to-Noise Ratio (S/N) Analysis

We analyzed all the results we reached using Takeshi's method in the field of experiment analysis charts using the Mini-Tab program analysis, where the results were within the applicable confidence interval, less than 5%, the probability value as shown in Table5. Weight loss (P) and thickness loss (ΔL) due to frictional wear were determined by experimentally designing each set of controls using Taguchi techniques, and signal-to-noise (S/N) ratios optimized the measured controls. Minimum weight and thickness loss due to corrosion are very important to improve product quality.

Table 5. Experimental findings and S/N ratio value

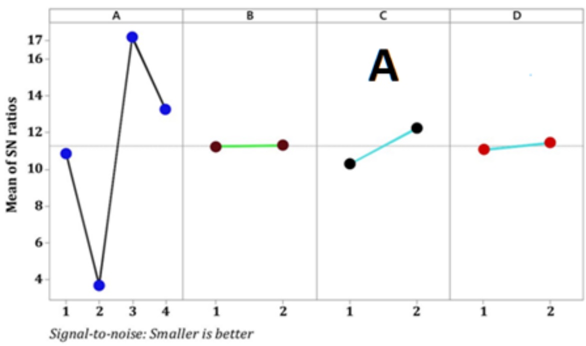
Degradation modes	B	C	D	P	S/N ratio for P	ΔL	S/N ratio for ΔL
	rpm	(N)	(µm)	(g)	(dB)	(mm)	(dB)
Raw material	180	4,65	1000	0,2910	10,7221	0,10	20,0000
Raw material	180	9,3	2000	0,1050	19,5762	0,05	26,0206
Raw material	355	4,65	2000	0,5170	5,7302	0,45	6,9357
Raw material	355	9,3	1000	0,4260	7,4118	0,20	13,9794
Ex -sunlight	180	4,65	1000	0,4990	6,0380	0,10	20,0000
Ex-sunlight	180	9,3	2000	0,7530	2,4641	0,30	10,4576
Ex-sunlight	355	4,65	2000	0,5710	4,8673	0,20	13,9794
Ex-sunlight	355	9,3	1000	0,8550	1,3607	0,35	9,1186
Ex-UV	180	4,65	1000	0,1350	17,3933	0,05	26,0206
Ex-UV	180	9,3	2000	0,1490	16,5363	0,10	20,0000
Ex-UV	355	4,65	2000	0,2480	12,1110	0,30	10,4576
Ex-UV	355	9,3	1000	0,0728	22,7574	0,15	16,4782
Ex-heat & cold	180	4,65	1000	0,4920	6,1607	0,25	12,0412
Ex-heat & cold	180	9,3	2000	0,2860	10,8727	0,10	20,0000
Ex-heat & cold	355	4,65	2000	0,1081	19,3235	0,45	6,9357
Ex-heat & cold	355	9,3	1000	0,1450	16,7726	0,40	7,9588

P (Weight loss total mean value) = 0.3531g and P (S/N ratio, total mean value) = 11.2561 dB. ΔL (thickness loss total mean value) = 0.22 mm and ΔL (S/N ratio, total mean value) = 15.0239 db. The "less is better" formula was used to calculate the S/N ratio bids. As shown in Tab 6. In terms of the values of the S/N ratios to monitor the weight loss and the decrease in the thickness of the tube after all the friction corrosion experiments were calculated by calculating the average values of the weight loss and the thickness, which P (Weight loss total mean value) = 0.3531g and P (S/N ratio, total mean value) = 11.2561 dB. ΔL (thickness loss total mean value) = 0.22 mm and ΔL (S/N ratio, total mean value) = 15.0239 db. The "less is better" formula calculates the S/N ratio bids. As shown in Table 6. The values of the S/N ratios to monitor the weight loss and the decrease in the tube thickness after all the friction corrosion experiments were calculated by calculating the average values of the weight loss and the thickness, respectively 0.3553 g and 0.22 mm. Similarly, the average values of the S/N ratio for weight loss and fish loss were calculated to be 11.2561 dB and 15.0239 dB, respectively, where we analyzed the effect of each control factor (deterioration mode, rotational speed, spring pressure force, and abrasive paper). Weight loss and thickness loss were performed using a weight loss and the optimum thickness loss control factors “S/N” response schedule" as per Table 6.

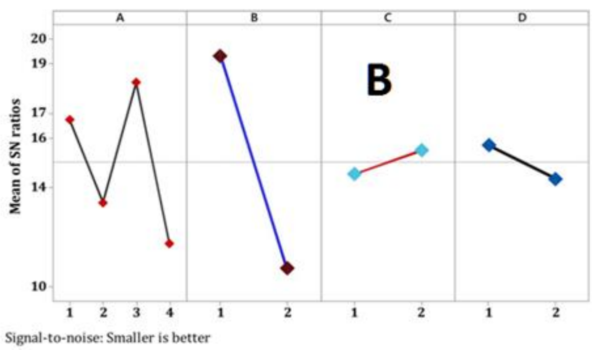
Table 6. Experimental values for Optimal Levels of Weight Loss (P) and Values for Optimal Levels of Thickness Loss (ΔL) Control Factors

Levels	Weight Loss (P)				Thickness Loss (ΔL)			
	A (months*3)	B (rpm)	C (N)	D (μm)	A (months*3)	B (rpm)	C (N)	D (μm)
Leve1	10,860	11,220	10,293	11,077	16,73	**19,32**	14,55	**15,70**
Leve2	3,683	**11,292**	**12,219**	**11,435**	13,39	10,73	**15,50**	14,35
Leve3	**17,199**	-	-	-	**18,24**	-	-	-
Leve4	13,282	-	-	-	11,73	-	-	-
Delta	13,517	0,071	1,926	0,358	6,51	8,59	0,96	1,35
Rank	1	4	2	3	2	1	4	3

Loss of weight and thickness after 45 minutes of corrosion (Figs. A and B) show the optimal treatment parameters for the control factors to reduce the weight loss value as well as the value of the loss of thickness of pipes made of HDPE80 material, where the corrosion of natural gas transmission pipes can be easily determined as the level of each control factor is found, according to the S/N ratio, to be higher at levels of this control factor.



(a)

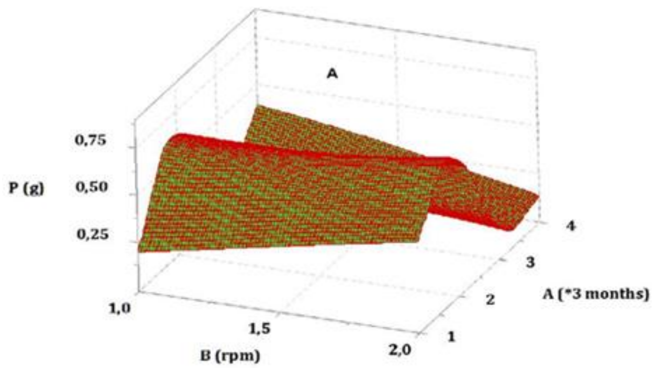


(b)

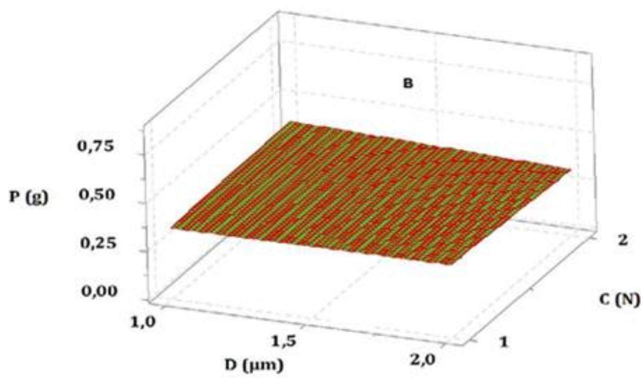
Fig. 2. (a) Effect of process parameters on the average S/N ratio for weight loss (P) and (b)effect of process parameters on the average S/N ratio for thickness loss (ΔL).

Accordingly, the stories and S/N ratios of factors influencing weight loss for HDPE80 were determined as factor A (level 3, S/N = 17,199), factor B (level 2, S/N = 11,292), factor C (level 2, S/N = 12,219), and factor D (level 2, S/N = 11,435). In other words, the optimal value obtained under the influence of UV aging agents (A3) is 355 rpm of rotating speed (B2), constant pressing force (C2), at a rate of 9.3 N, and using D abrasive paper with a grain size of 2000. (10.3μm) (Fig.2A). Similarly, the levels and S/N ratios of the factors give ΔL the best definition as Factor A (Level 3, S/N = 18, 24), Factor B (Level 1, S/N = 19, 32), Factor C (Level 2, S/N = 15,50), and the D factor (Level 1, S/N = 15,70). In other words, the friction factors affecting the thickness loss of HDPE80 material were demonstrated, as the highest ΔL value was obtained using (A3) UV, with a rotational speed of (B2) of 180 rpm, with a continuous compressive force (C2) at a rate of 9.3 N, and using D abrasive paper with a grain size of 1000 (18.3 m) (Fig. 2B).

Exposure to radiation emitted from a UV lamp with a wavelength equal to (=365 nm) increases weight loss and thickness in the friction zone, where the most influential factor in premature aging and, thus, weight loss and thickness of the studied tubes were observed. Effect on the weight loss, and the increase in the compressive strength rate causedCaused a significant increase in the value of the lost weight. [9], this feature causes rapid wear of plastic materials during processing and shortens their life of use.



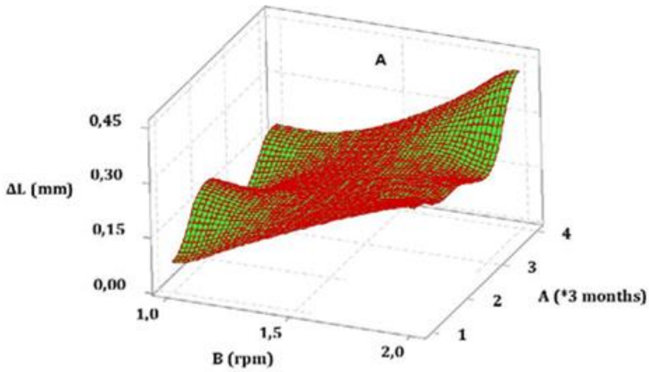
(a)



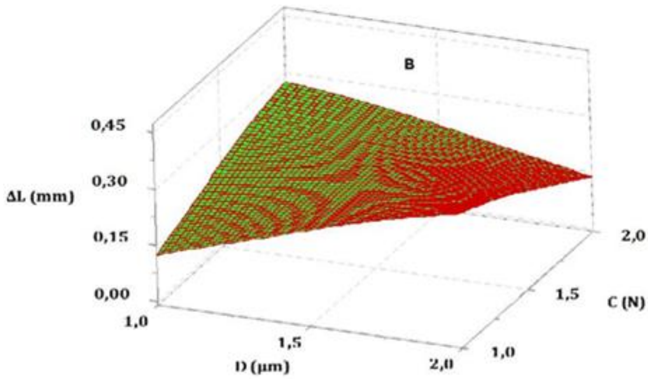
(b)

Fig. 3. Effect of the Weight loss (P) parameters A (B: Spindle speeds,A: Modes of degradation months) and B (D: abrasive paper ,C: Load pressure)

Also, the low rotational speed and the abrasive paper grains with smaller diameters affected the thickness loss value of the tested tubes, as well as the high compressive strength, which directly affected the thickness loss, as shown in (Fig.3) and (Fig.4) that show the effects of the control factors that using The Taguchi method validated the results obtained from experimental studies.Figure 4. Effect of the Weight loss parameters (P) (B: Spindle speeds,A: Modes of degradation months) and (D: abrasive paper ,C: Load pressure).



(a)



(b)

Fig. 4. Effect of the thickness loss (ΔL) parameters A (B: Spindle speeds,A: Modes of degradation months) and B (D: abrasive paper ,C: Load pressure)

6.2. Method Anova and Taguchi Analysis

ANOVA is a statistical method used to determine the individual interactions of all the control factors in a test design. In this study, ANOVA was used to analyze the effect of the degradation of HDPE80 pipes during the process, 6 months and 60 hours of exposure to ultraviolet radiation, rotational speeds, pressure forces, and an abrasive medium with grains of different diameters (10.3 and 18.3 µm).

The ANOVA results for weight loss and thickness loss are presented in Table7. This analysis was performed with a significance level of 5% and a confidence level of 95%. The significance of the control factors is determined in an ANOVA by comparing the control factors. The fourth column of the table shows the percentage of the contribution value of each factor, which indicates the degree of impact on process performance. According to Table 6, the percentage contributions of factors A, B, C, and D to mass loss were found to be 63,86%, 0,10%, 0,74%, and 0,16%, respectively. Thus, the most important factor affecting mass loss was rotational speed (factor, 63,86%). According to the ANOVA results, the percentage contributions of factors A, B, C, and D on thickness loss were found to be 16.99%, 47.70%, 0.95%, and 1.89%, respectively. This showed that the most effective factor in corrosion was load pressure (B-factor, 47.70%). The error percentage was considerably low at 35,13% and 32,47% for P and ΔL respectively.

Table 7. Taguchi Analysis for Weight Loss (P) and thickness loss (ΔL) versus A; B; C; D

		Weigh Loss (P)			Thickness Loss (ΔL)		
Source	DF	Contribution	Seq MS	F-Value	Contribution	Seq MS	F-Value
A	3	**63,86%**	**0,136028**	**5,45**	16,99%	0,019838	1,57
B	1	0,10%	0,000652	0,03	**47,70%**	**0,167139**	**13,22**
C	1	0,74%	0,004747	0,19	0,95%	0,003314	0,26
D	1	0,16%	0,001034	0,04	1,89%	0,006631	0,52
Error	9	35,13%	0,024944	-	32,47%	0,012642	-
Total	15	100,00%	-	-	100,00%	-	-

7. Regression Analysis of Weight Loss and Thickness Loss

Regression analyses are employed for modeling and analysis of multiple variables when there is a link between a dependent variable and one or more independent variables [30].

In this study, the dependent variables are the weight lost (P) and the thickness lost due to wear of the material by friction (ΔL). In contrast, the independent variables are the deterioration mode (M) during four equal periods of one full year (3, 6, 9, and 12 months), two rotational speeds (V), two pressing forces (F), as well as the use of two types of abrasive paper as a coarse medium (A). The equations of weight loss, thickness of the material, corrosion of the studied surfaces, and regression analysis were used to obtain a prediction. These predictive equations were made for both linear and quadratic regression models. Predictive equations for handlebar weight and loss thickness wear obtained by the linear regression model are shown below Eqns (4; 4a) and Eqns (5; 5a).

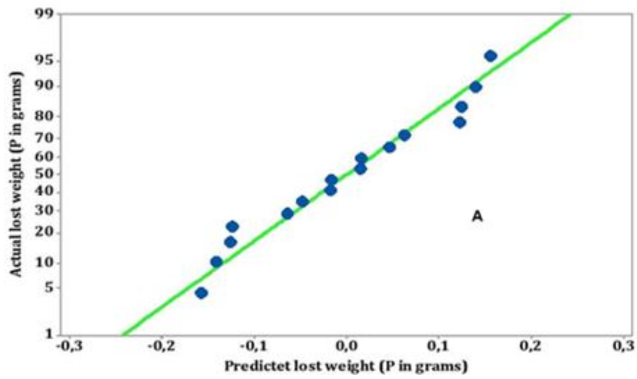
$$P_L = 0{,}111 + 0{,}335\ M - 0{,}122\ V - 0{,}083\ F - 0{,}013\ A \tag{4}$$

$$\text{Model Summary : } (S = 0{,}165193\ ;\ R\text{-sq (adj)} = 81{,}48\%\ \text{ and } R\text{-sq (pred)} = 53{,}70\%\ ) \tag{4a}$$

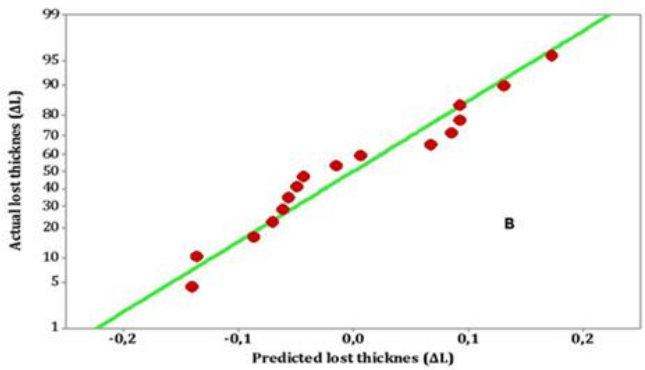
$$\Delta L_L = 1{,}1412 + 0{,}0468\ M + 0{,}0201\ V + 0{,}0295\ F + 0{,}0432\ A \tag{5}$$

$$\text{Model Summary: } (S = 0{,}0144940\ ;\ R\text{-sq(adj)} = 98{,}80\% \text{ and } R\text{-sq(pred)} = 91{,}02\%) \tag{5a}$$

Here, the lost weight (P) and the lost thickness resulting from wing wear by friction (ΔL) are shown, respectively. In (Fig.5), The comparison of actual test results and predicted values, which the linear regression model obtained, are given, R^2 values of the equations which were obtained by the linear regression model for (P and ΔL) were found to be 81,48% 98,80% respectively.



(a)



(b)

Fig.5. Comparison of the linear regression model with experimental results for the lost weight (PL) (a) and (b) the lost thickness resulting from wing wear by friction (ΔL)

The predictive equations for the quadratic regression of the lost weight (P) and the lost thickness resulting from wing wear by friction (ΔL) are given below: Eqns (6; 6a) and Eqs (7;7a).

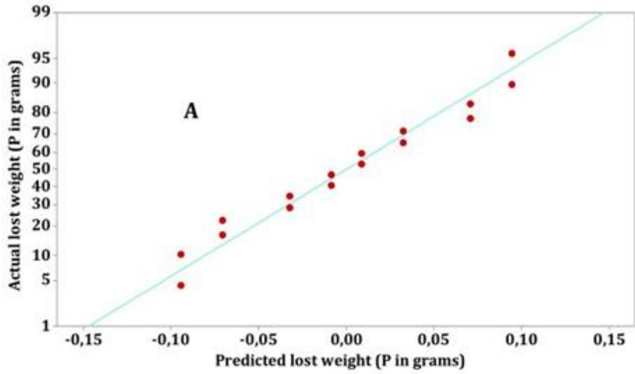
$$P_q = 0{,}41 + 0{,}520\ M + 0{,}696\ V - 0{,}789F + 0{,}308\ A - 0{,}234\ M*V + 0{,}202\ M*F - 0{,}092M\ *P \tag{6}$$

$$(\text{Model Summary}: S = 0{,}141413;\ \ R\text{-sq(adj)} = 93{,}21\%\ \text{and}\ R\text{-sq(pred)} = 66{,}07\%) \tag{6a}$$

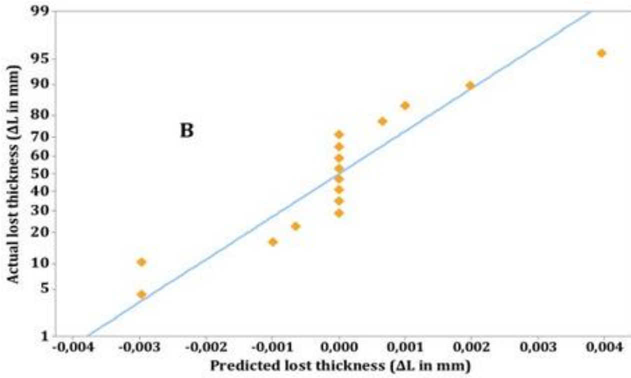
$$\Delta L_q = 1{,}3429 - 0{,}0153M + 0{,}0212V - 0{,}0290F - 0{,}02739A - 0{,}00643M * M + 0{,}02768M * F \tag{7}$$

$$(\text{Model Summary}: S = 0{,}0063214;\ R\text{-sq (adj)} = 99{,}89\%\ \text{and}\ R\text{-sq (pred)} = 98{,}29\%) \tag{7a}$$

Here Pq and ΔLq show the predictive equations for weight loss and thickness loss due to frictional wear of the material. In (Fig.6), The test results and comparison of the expected values obtained by the quadratic regression model are shown. It turns out that there is a perfect relationship between the predicted values and the test results. Were found to be 93,21% and 99,89%, respectively. Therefore, very expected values were obtained through the quadratic regression model compared to the linear regression model, which proved the success of the quadratic regression model in losing weight and thickness resulting from corrosion of the studied material.



(a)



(b)

Fig. 6.Comparison of the quadratic regression model with experimental results for the lost weight (Pq) and the lost thickness resulting from wing wear by friction (ΔLq)

8. Confirmation of Experiments

Here is the overall rate for WLTMV and TLTMV for the total mean value of weight loss (P) in grams (g) and the total value of thickness loss (ΔL) in millimeters, respectively, during the experiment optimally Eqn.(8), and n is the number of control factors for the expected missing value. The results are clearly shown in Tabs. (8) show that the expected value agrees well with the experimental value.

Table 8. Weight loss total mean value (P), and Thickness loss total mean value (ΔL)

		Predicted A3, B2,C2 and D2	Experimental A3, B2,C2 and D2
WLTMV (g)	Mean value (P)	0.408	0.353
TLTMV (mm)	Mean value (ΔL)	0.167	0.22

$$\gamma = \gamma_m + \sum_{i=1}^{\eta} (\gamma_I - \gamma_m) \tag{8}$$

Where:

γ_m : The total mean value of weight loss and the total value of thickness loss (ΔL);

γ_I : The mean of WLTMV and TLTMV at an optimal level;

η : The number of control factors.

9. Conclusions

This work used the Taguchi method to determine optimal machining parameters. This is done by using friction and corrosion experiments, which contribute to the destruction of the polymer (HDPE 80) material by weight loss. After evaluating the experimental results using ANOVA, we found the following:

- The optimum levels of the control factors for minimizing the lost weight (P) and the lost thickness resulting from wing wear by friction (ΔL) using S/N rates were determined. The optimal conditions for lost weight and thickness were observed at A3, B2, C2, and D2 (i.e., Degradation mode = UV, Rotation speed = 355 rpm, Load = 9.3N, and Abrasive paper = 10.3 Grade) and A3, B1, C2, and D1(Degradation mode = UV, Rotation speed = 180 rpm, Load = 4.65 N and Abrasive paper = 18.3 Grade), respectively.

- A vertical milling machine was used, with several experiments conducted using a Taguchi L16 (4^1*2^3) multifactor design with a mixed orthogonal array. Analysis of variance (ANOVA) to determine corrosion due to weight loss and thickness loss for natural gas transportation pipe made of polyethylene (HDPE 80) under the influence of the parameters of abrasive paper grain diameter, cutting speed, and continuity of pressure force over two hours, with each experiment lasting 15 minutes before inspection.

- The results clearly showed that the exposure of the HDPE 80 material to ultraviolet radiation directly contributes to the deterioration of the material by losing its thickness and weight through friction and corrosion.

- According to the results of the statistical analysis, it was found that the medium of use is the most significant factor for Weight loss with a percentage contribution of 63,86% and that the cutting speed was the most critical parameter for thickness loss by wear with a percentage contribution of 47,70%.

- Developed quadratic regression models demonstrated a perfect relationship with high correlation coefficients (P = 0,661 and ΔL = 0.983) between the measured and predicted values for lost weight and thickness.

- After conducting experiments and analyzing their results, it was shown that the effect of aging under the deterioration factor of ultraviolet rays and sunlight on the surface weakens the corrosion resistance of the studied polyethylene. Suppose that aging under normal and accelerated conditions leads to the deterioration of the properties of polyethylene. Therefore, a potential model has been found that contributes to significant improvement in mechanical and terbological degradation. In future studies, the effect of different transported fluids on the deterioration of plastic materials will be studied by simulation under real-world conditions.

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