Investigation of hardness and tensile strength ratio of a polyethylene blend

Konstantin Chukalov
Technical University Sofia, Bulgaria,branch Plovdiv
chukalov@tu-plovdiv.bg

Abstract: *In this paper, the results of Shore D hardness and tensile strength according to ISO 10319 were investigated. The results were processed statistically by creating a trend line and regression analysis in order to study in details the existing relationship*
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Keywords: *HARDNESS,TENSILE STRENGHT,TRENDLINE,MECHANICAL PROPERTIES*

1. Introduction

Mechanical properties are characteristics that determine how the material reacts to external forces. The main mechanical properties are: hardness, strength, stiffness, creep resistance, fatigue resistance, etc. The possibility of determining mechanical properties such as tensile strength, yield strength and fatigue by hardness is well known and often used in engineering practice. Hardness is the property of a material to resist plastic deformation, a property that only applies to the surface layer[1].Tensile strength is the maximum stress that a specimen can withstand. The hardness-tensile strength relationship is used because hardness testing is non-destructive, experimental data are obtained quickly,there is no need to manufacture standardized specimens, and the test is simple[2]. The equation for the relationship between hardness and tensile strength is:

$$UTS=H.k \tag{1}$$

The range of the coefficient k are well known for a number of materials such as brass, steel, aluminum alloys, etc.Polymer blends are like alloys mixing of two polymers aims to obtain a new material with different properties. Thermoplastic blends such as PE are of wide interest due to the large variety of PE-HDPE, LDPE, etc. PE blending is a common industrial practice[3].

2. Materials and methods

The material under study is a PE blend, with a concentration of HDPE and LDPE 75 to 25 percent. Polyethylene is a thermoplastic plastic with an amorphous-crystalline structure. It is obtained by polymerization with high (50 MPA), medium (3-7 MPa) and low pressure[4]. At room temperature, PE is a hard and elastic polymer with high chemical resistance.
The Shore durometer is used to measure the hardness of polymers (fig.1)[5]. Higher values indicate higher resistance to penetration, and lower values indicate softer material. There are different Shore measurement scales[6].Shore measurement is performed in dimensionless unit [7].For the purpose of the article, the D scale was used, which is intended for hard plastics. The durometer was calibrated, reference blocks were used before the tests.

Fig. 1 *Shore D(durometer) tester*

The maximum tensile strength measurements were performed on a calibrated universal mechanical testing machine (fig.2). The scope and jaws correspond to the test conditions of the test. The strain gauge is capable of applying a maximum force of 10 kN.

Fig. 2 *Universal tensile machine*

16 samples were made with dimensions of thickness 1.4 ± 1mm, width 200 ± 1mm. 4 hardness tests were made from each sample, after which the values were averaged.
Based on the experimental results, a trendline and a linear regression equation were created. The trendline shows the direction of the relationship, and the regression equation shows the stochastic values of the process. The regression equation includes points interpolated by the graph of the linear equation

3. Results and discussion

The results of the hardness measurement are shown in a table (tab. 1), (fig 3).The values are averaged to 3 decimal places. The requirements of the Shore hardness testing standard ISO 7619 are met.

Table 1: *Hardness Shore D results*

Sample	Hardness Shore D				Average
1	49.4	52.5	49.6	49.9	50.35
2	52.2	49.7	55.1	53.7	52.675
3	50.9	50.4	48.9	51.2	50.35
4	54.8	52	53.5	49.5	52.45
5	49.8	48.6	48.2	49.3	48.975
6	55.2	55.4	51	52.6	53.55
7	49.7	50.9	51.7	51.9	51.05
8	50.2	49.3	47.3	49.1	48.975
9	48.8	46.8	50.8	48.7	48.775
10	58.1	52.8	55.3	52.7	54.725
11	47.8	49.3	47.8	48.7	48.4
12	58.1	46.8	50.8	48.7	51.1
13	47	48.2	50.2	53.6	49.75
14	51	52.9	50.4	50.2	51.125
15	47.8	48.9	51.3	49.9	49.475
16	49.8	51.6	51.9	52.2	51.375

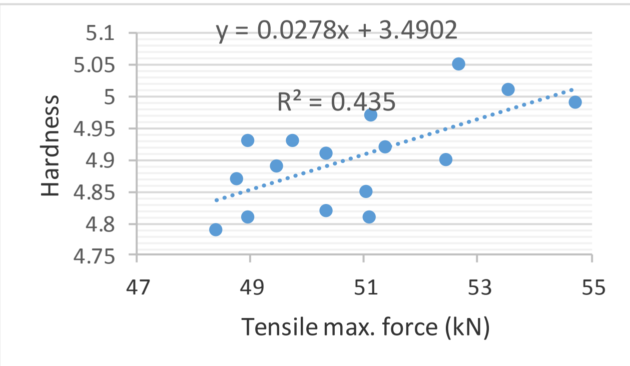
Fig.3 *Test result sample 10,testing No 3.*

The results of the average values of the measured hardness and maximum tensile strength are presented in a table, tab. 2.

Table. 2: *Hardness and ultimate tensile force results*

Sample No	Hardness	Ultimate tensile force (kN)
1	50.35	4.91
2	52.675	5.05
3	50.35	4.82
4	52.45	4.9
5	48.975	4.81
6	53.55	5.01
7	51.05	4.85
8	48.975	4.93
9	48.775	4.87
10	54.725	4.99
11	48.4	4.79
12	51.1	4.81
13	49.75	4.93
14	51.125	4.97
15	49.475	4.89
16	51.375	4.92

Based on the results, a scatter plot is presented and a trendline is constructed (fig.4)[8]. The hardness is chosen as the independent variable, and the maximum tensile force as the dependent variable.



*.**Fig.4** Scatter plot and trendline*

The coefficient of determination (R^2) shows how well an independent variable in a statistical model predicts the dependent variable[9]. R2 results between 0.25 and 0.5 indicate a moderate relationship between the variables. R^2 is in the range between 0 and

1. Based on the experimental results, a linear regression model was created, shown in tab. 3 and tab. 4

Table 3 *:Characteristics of the regression model*

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	21.60182	21.60182	10.81151	0.005389
Residual	14	27.97255	1.998039		
Total	15	49.57438			

Significance F is less than 0.05, which means that the null hypothesis is rejected and that the equation is statistically significant.

***Table** 4 Characteristics of the regression model*

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-26.0263	23.37341	-1.1135	0.284247
Tensile max. F	15.67266	4.766499	3.288086	0.005389

The regression equation has the form:

$$y=15.67x-26.03 \quad (2)$$

The analysis of the coefficients, P-value shows that the coefficient a is significant, and the coefficient b is insignificant. The residuals and standardized residuals are shown in table 5

Table 5*: Residuals and standard residuals*

Observation	*Predicted Hardness*	*Residuals*	*Standard Residuals*
1	50.9265	-0.5765	-0.42216
2	53.12067	-0.44567	-0.32636
3	49.51596	0.83404	0.610754
4	50.76977	1.680227	1.230404
5	49.35923	-0.38423	-0.28137
6	52.49377	1.056234	0.773464
7	49.98614	1.06386	0.779048
8	51.23995	-2.26495	-1.65859
9	50.29959	-1.52459	-1.11644
10	52.18031	2.544688	1.863434
11	49.04578	-0.64578	-0.47289
12	49.35923	1.740766	1.274736
13	51.23995	-1.48995	-1.09107
14	51.86686	-0.74186	-0.54325
15	50.61305	-1.13805	-0.83337
16	51.08323	0.291774	0.213661

Residuals are a term in statistics that indicates the difference between an observed value and a predicted value[10]. They are also known as model error. It is noted that 14 out of 16 residual values are within ±2 and only 2 are out of the range ±2 but in the range of ±3. The results are within the accuracy of the Shore D hardness measurement. Standard residuals deviation is the standard deviation of residual values, or the difference between a set of observed and predicted values. The standard residuals indicate how useful the model is. All standard residuals are within ±2[11]. These values indicate the adequacy of the model.

4. Conclusions

Based on the experimental results and the created mathematical models, the following conclusions can be drawn:

• The range and distribution of the results for hardness and tensile strength do not show significant deviations.

• No discrepancies were observed during the tests

• The created trendline shows the trend of the results

• The Significance F value rejects the null hypothesis and proves that the model is statistically significant.

• The R2 value showed a moderate strong relationship between the results

• The analysis of the residuals and standardized residuals proves that there are no critical deviations from the created model.

5.References

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