Comparison Study of the Mechanical, Thermal and Thermomechanical Properties of PVC Turkey Doors

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Abstract

In this study, the mechanical, thermal, thermomechanical properties as well as lifetime of two different companies of Turkey doors (Firat and Nova) have been measured. The tests were carried out on it, included: The (tensile, bending, impact, hardness, thermal conductivity, thermogravimetric analysis (TGA) and Thermomechanical analysis (TMA) tests).

From the TGA curves the activation energy, thermal stability and lifetime are determined different heating rates (2, 5, 10, 20 and 40 ˚C/min), while the glass transition temperature (T_g) and softening point (T_s) are determined from (TMA) curves.

The results showed that the Firat was overcome Nova in (mechanical, thermal conductivity, thermal stability and lifetime), while the glass transition temperature (T_g) and softening point (T_s) they have the same values.

Keywords: PVC, mechanical properties, thermal conductivity, TGA, Lifetime, TMA.

Introduction:

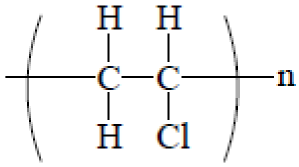
The polyvinyl chloride PVC is one of the most commonly used manmade polymers because of the unrivalled combination of properties that it offers. Its ratio of economic cost to performance makes it immediately more accessible than most other materials and the diversity of ways in which it can be used challenges the imagination, from roofing membranes to credit cards, from children’s toys to pipes water [1].

The PVC competes in many applications because of its excellent properties like [2]: high electrical insulation, high resistance for abrasion, low diffusion for humidity, good flexibility within range of temperatures and resistance to water, bases, acids, alcohols, oils, and aliphatic hydrocarbon components (compounds).

There are two important kinds of PVC [2]:

- Rigid PVC which is used in fabrication of pipes and plastic plates (sheets).
- Flexible PVC, which is composed from polymer with addition of plasticizers. This type of PVC used in fabrication of films, coating purposes and production of industrial leathers.

The vinyl chloride monomer consists of a carbon-carbon bond, a pendent Chloride atom, and three hydrogen atoms.



Where n is the degree of polymerization, i.e. the number of repeat units in the molecular chain. This monomer polymerizes by the addition (free radical) polymerization method [2].

Experimental Part:

I - Mechanical Test:

The tensile behavior of samples was determined at room temperature using tensile testing machine model H50KT manufactured by (Tinius Olsen/UK). The samples were prepared in accordance with ASTM-D638. The specimen was loaded between two manually adjustable grips of a (2000 N) computerized tensile testing machine, with an electronic extensometer.

Flexural strength is determined by 3-point bend test. The test specimen accordance with ASTM-D790 were used for test. Using bending instrument model H50KT manufactured by (Tinius Olsen/UK).

The Charpy impact strength of samples was tested using the standard test specimen in accordance with ISO-179, having 45˚ V-notch with 2mm deep. (Charpy test) model IMI manufacturer by Amityville/ New York this instrument consists mainly of pendulum and energy gauge.

The shore hardness of the samples was measured using a Dorometer device (fabricated by TIME GROUP INC Company) according to the ASTM (D 2583-67). The Dorometer instrument has an indenter projecting below the bas (face) of the pressure foot. The indenter was pressed with sufficient band force for 5 seconds into the plastic specimen perpendicularly so that the base took rest on the plastic surface. The amount of indentation registered directly on the dial indicator.

II - Thermal Test:

Lee's disc instrument manufactured by the Griffen and George Company, was used to calculate the thermal conductivity of the samples under test. Instrument consists of three discs of brass (40 mm diameter by 12.25 mm thickness) and a heater. Thermogravimetric Analysis Instrument (TGA):

(TGA) instrument model TGA4000 manufactured by (PerkinElmer/Germany). It is Consists of a sample pan that is supported by a precision balance. That pan resides in a furnace and is heated or cooled during the experiment. The mass of the sample is monitored during the experiment. A sample purge gas controls the sample environment. This gas may be inert or a reactive gas that flows over the sample and exits through an exhaust. Essentially, separate measurements are carried out at different linear heating rates (2, 5, 10, 20, 40 C˚/min) for all samples. The sample weight about (20-30 mg).

III -Thermomechanical analysis test:

All of the thermomechanical experiments (expansion and penetration mode) presented in this work carried out by LINSEIS, TMA PT1000/German origin. Preparation of samples as cylinder with approximate dimensions of (20 mm height and 5 mm diameter). The samples were securely place on the sample holder and a (50mN) force was applied to the sample in the penetration mode only, followed by a heating rate of 5˚C/min from ambient up to 120˚C.

Results and Discussion

I - Mechanical properties:

- Tensile test:

Stress-strain curves of PVC doors (Firat, Nova) are shown in figure (1). From these tensile curves, we can get young's modulus, ultimate tensile strength, elongation at max. and elongation at break, which display in tables (1).

From figure (1) and table (1), the Firat door overcomes clearly on the Nova door in all tensile properties. Firat is much toughness than Nova sample, as shown in fig. (2). All results of the tensile properties are good agreement with their values in literatures [3].

- Bending test:

From figures (3), the flexural strength is determined. The Firat door has higher flexural strength (56.6 MPa) than Nova door (54.8 MPa) table (1). This difference in the flexural strength because there are difference in the bonding between the chains [4].

- Impact test:

The impact properties of materials are directly related to overall toughness. The table (1) show that The Firat door has impact strength value (30.8 KJ/m^2) more than Nova door (21.7 KJ/m^2), because of the area under stress- strain curve (fig. (2)) is greater for Firat door than that Nova. All the values of impact strength are good agreement with [5].

- Hardness Shore D:

The hardness of is equal of two types of (Firat and Nova) Table (4) illustrates the values of hardness. Which agreement with [6].

II - Thermal properties:

- ***Thermal Conductivity:***

From Table (1), it can be noticed, that the average value of the thermal conductivity of this material is less than (0.45W/m.^{o}C) which reflects the high resistance of those materials to heat transfer. This means, their suitability to be used as thermal insulators, this low thermal conductivity is due to the fact that these polymers have no free electrons and low phonon velocity [7]. The table (5) show that Firat has thermal conductivity value higher than that Nova. The results of thermal conductivity of PVC Agreement with [8].

- ***Thermal stability and Degradation:***

TGA curves of PVC doors are shown as figures (4) and (5) respectively, at different heating rates (5, 10, 20 and 40 ˚C/min). From these curves, we can:

i. **Identify the kind of polymer** from their decomposition pattern [9].

ii. **Thermal stability:**

The reaction is characterized by two temperatures, T_i and T_f, which are called the procedural decomposition temperature and the final temperature, respectively.

According to Figures (4) and (5), the weight loss curve has been shifted to the higher temperatures when the heating rate is increased. In all experiments, final temperature was 800 ˚C, from 240 – 350 ˚C the polymer degradation but above 350 ˚C the sample degradation with 50% [16], although the decomposition curves of PVC doors are close to each other at the heating rate rang of (5-20 ˚C/min). Decomposition takes place above 250 ˚C; the sample first suffers a loss of about 2% due to moisture and then, as expected decomposes in two steps [17]. At high heating rate, fast pyrolysis was observed [10]. Figures (6), (7), (8) and (9) shows that Firat has higher thermal stability than the Nova at different heating rates.

iii. Activation energy:

TGA curves are used to determine the kinetics of thermal decomposition of polymer like activation energy of polymer. For estimating the activation energy at certain conversion levels (1%, 2.5%, 5%, 10%, 20%, 30%, 40%). Where the weight loss of sample is reduce at (99%, 97.5%, 95%, 90%, 80%, 70%, 60%) respectively. The conversion temperatures are determined for pipes and doors at different conversion levels. Where the conversion temperature are increase with increase the heating rates.

From the slope of figure (10) and (11), we estimate the activation energy of pipes and doors at different conversion levels. When the value of slopes be nearly constant, the conversion level is choice to determine the activation energy. Because the mechanism of degradation becomes stable. As shown in tables (2) and (3). The results are Good agreement the values of activation energy at (30%) with [11].

iv. Lifetime predictions:

The aging of polymers implies some type of degradation process usually involving the breaking of covalent bonds [12].

At conversion level 30% the lifetime are estimated for Firat and Nova doors by using equation: $t = \frac{Tc - Ti}{\beta}$ ………….. (*)

Where T_c is conversion temperature.

T_i is procedural temperature.

t is time degradation at T_c

From the figures (12) and (13), we can determine the lifetime of doors at different serves temperatures as displays in table (4). The lifetime is decrease with increasing temperature [13]. At serves temperatures from 60-80˚C the lifetime of Firat door is better than Nova door.

- ***Glass Transition Temperature (T_g) And Softening Point (T_s):***

The TMA test including two procedures (expansion mode & penetration mode):

a- *Expansion Mode:* The transition temperature derived from this procedure is considered the glass transition temperature. The occurrence of an abrupt positive change in the slope of the linear thermal expansion that indicates a transition of the material from one state to another figures (14) and (15) [14]. As shown in table (5), the Firat and Nova doors have glass transition temperature approximately equal.

b- *Penetration Mode*: The transition temperature derived from this procedure is referred to as the softening point, *Ts*. For most materials *Ts* is close to the *Tg* as measured in the expansion mode or as measured by differential scanning calorimetry [14]. Figures (16) and (17). The value of Ts may be affected by the applied force and the probe contact area. The table (5) shows the higher value of softening point for K.S.A pipe. The Tg and Ts values are agreement with [15].

Conclusions:

1- All the tensile properties of Firat doors are much than that of Nova doors.
2- The flexural strength of Firat doors is greater than that of Nova doors.
3- The Firat doors are tough (more impact strength) than Nova doors.
4- The Firat and Nova doors have the same values of hardness.
5- The thermal conductivity of Firat doors is greater than Nova doors. In general good insulation.
6- Firat doors are more thermal stability than Nova doors at different heating rates.
7- The 30% conversion level is best level for determined the activation energy and lifetime.
8- The activation energy of Firat is (108.35 KJ/mole) while it is (98.35 KJ/mole) for Nova doors.
9- The lifetime at 70˚C of Firat is (≈72 years) but it is (≈21 years) for Nova.
10- The Firat and Nova doors have the same values of T_g and T_s.

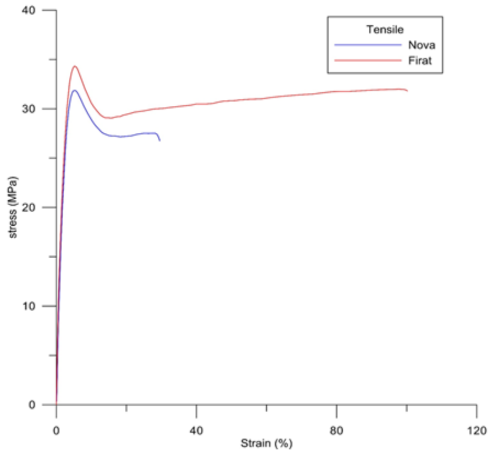


Fig. (1) stress-strain curves of Firat and Nova doors

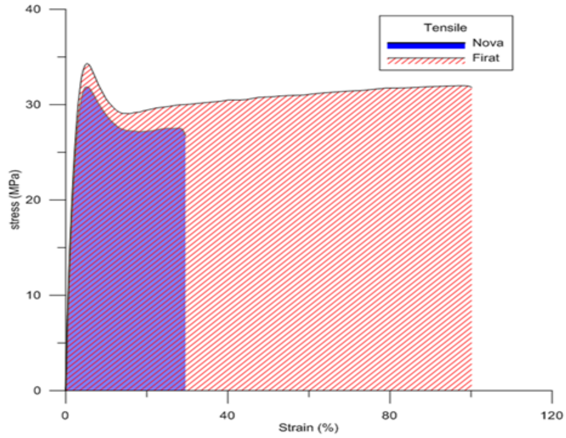


Fig. (2) the comparison toughness of Firat and Nova doors

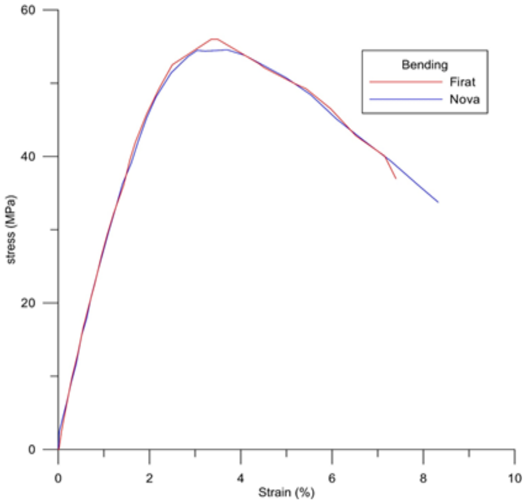


Fig. (3) the comparison of bending stress-strain curve of K.S.A and Egypt pipes

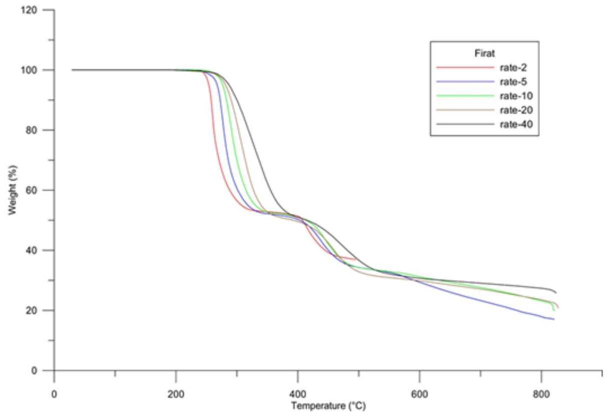


Fig. (4) the relation of weight% VS temp. of Firat door at different heating rates

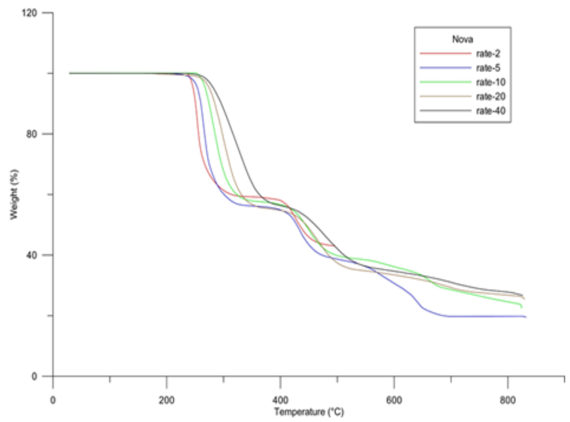


Fig. (5) the relation of weight% VS temp. of Nova door at different heating rates

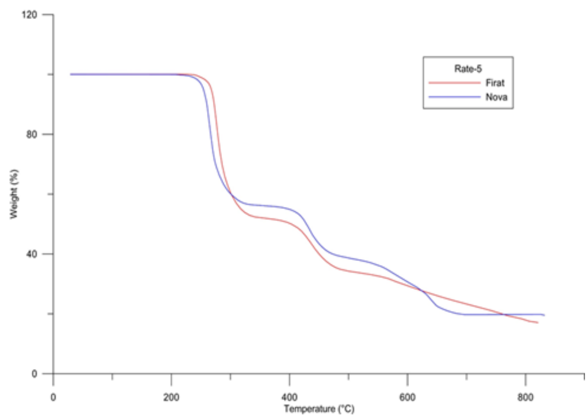
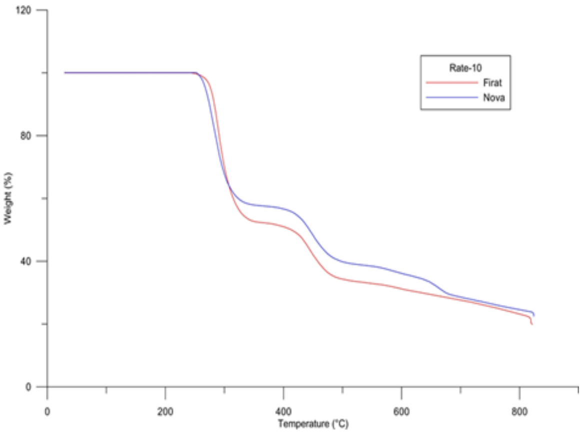


Fig. (6) the thermal stability of Firat and Nova doors at heating rate (5 °C/min)



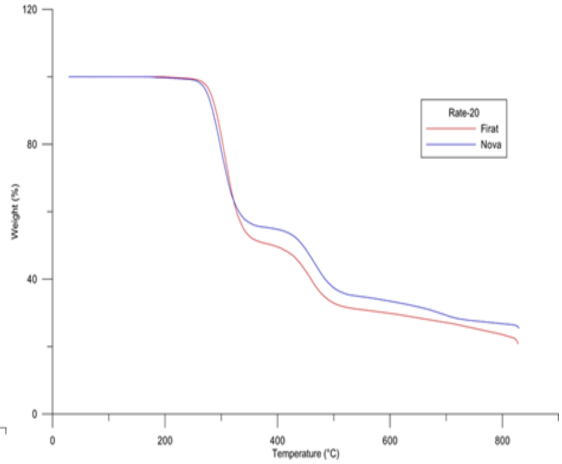


Fig. (7) the thermal stability of Firat and Nova doors at heating rate (10 °C/min)

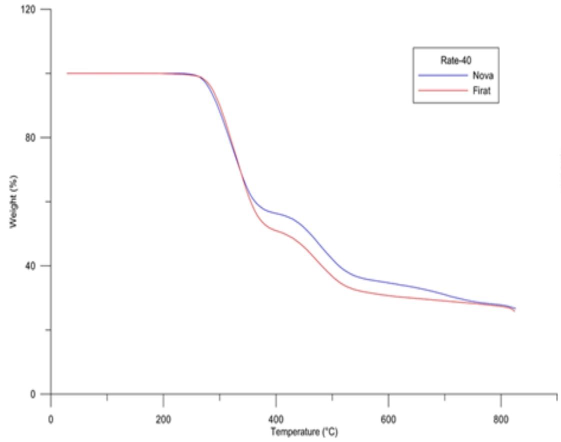


Fig. (9) the thermal stability of Firat and Nova doors at heating rate (10 °C/min)

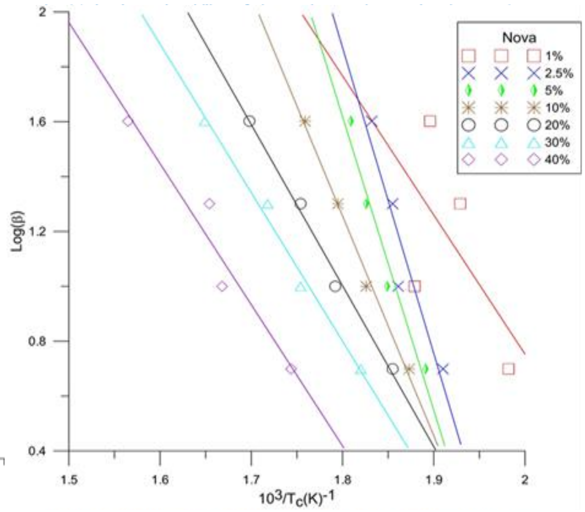


Fig. (10) temperature dependance of Logβ VS reciprocal absolute temperature for various weight loss for Nova door

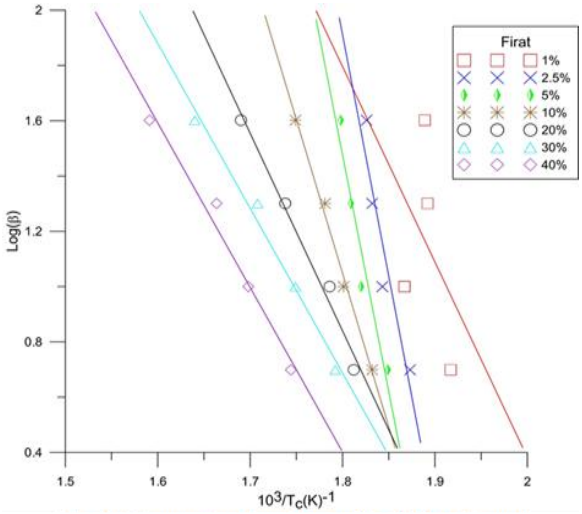


Fig. (11) temperature dependance of Logβ VS reciprocal absolute temperature for various weight loss for Firat door

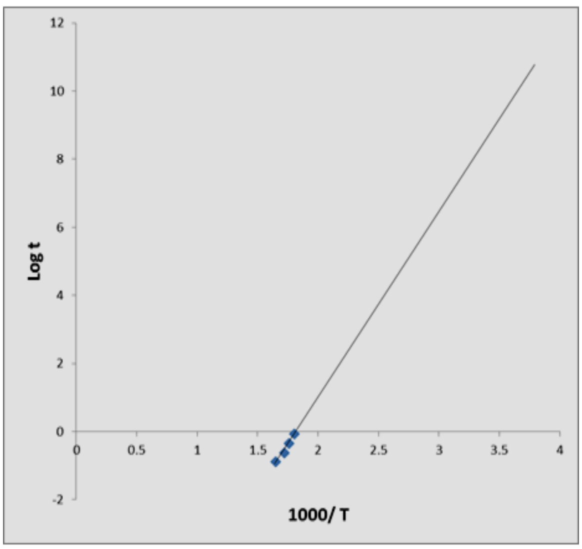


Fig. (12) the extrapolation relation of Logt VS $10^3/T$ for Firat door

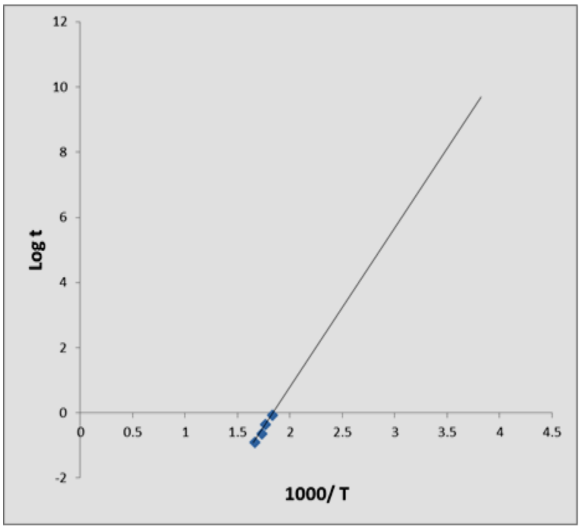


Fig. (13) the extrapolation relation of Logt VS 10^3/T for Nova door

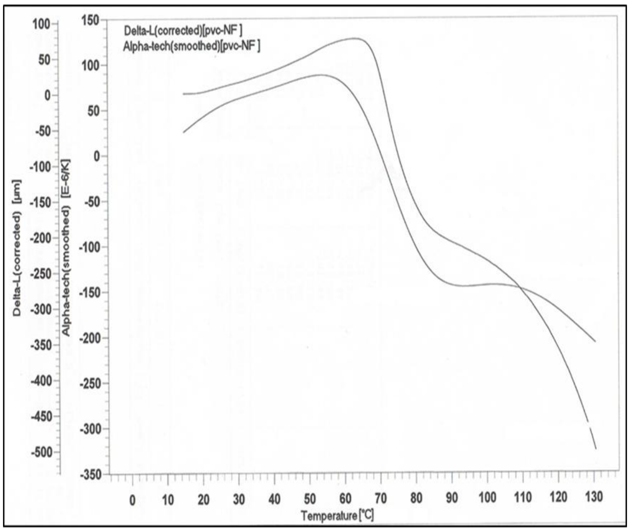


Fig. (14) Expansion Mode of Firat door

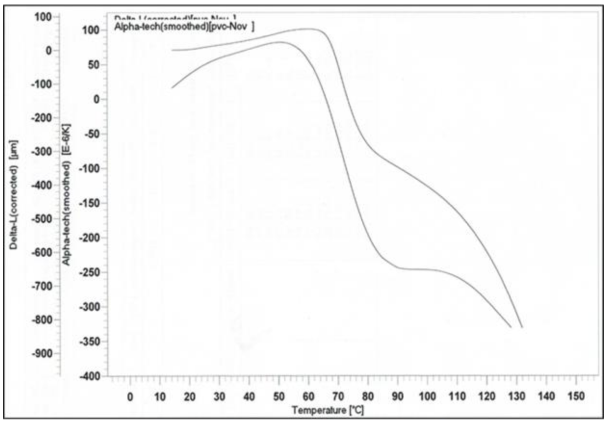


Fig. (15) Expansion Mode of Nova door

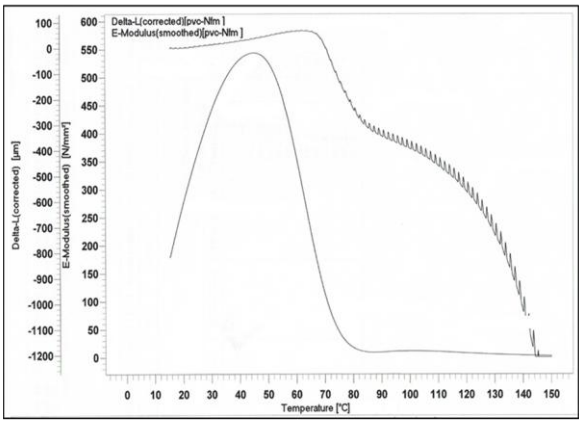


Fig. (16) Penetration Mode of Firat door

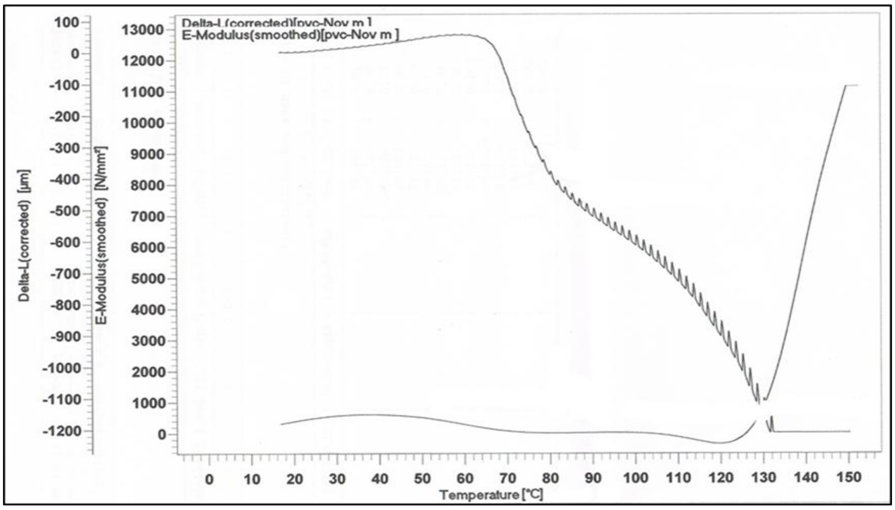


Fig. (17) Penetration Mode of Nova door

Table (1) mechanical and thermal properties of Firat and Nova doors

NO.	Properties	Firat	Nova
1	Young's Modulus (MPa)	1246.827	1214.642
2	Ultimate Tensile Strength (MPa)	34.5	32.25
3	Elongation at max (%)	5.456	5
4	Elongation at Break (%)	100.18	28.268
5	Flexural strength (MPa)	56.6	54.8
6	Impact strength (KJ/m^2)	30.883	21.780
7	Hardness shore D	80.7	80
8	Thermal conductivity (W/m.˚C)	0.21525	0.19545

Table (2) the values of activation energy of Firat at different conversion levels

Conversion %	slope	Ea (KJ/mole)
1	-7.067	128.45
2.5	-17.47	317.55
5	-17.12	311.19
10	-11.11	201.94
20	-7.15	129.96
30	-5.961	108.35
40	-5.954	108.225

Table (3) the values of activation energy of Nova door at different conversion levels

Conversion %	slope	Ea (KJ/mole)
1	-5.069	92.139
2.5	-11.15	202.67
5	-10.70	194.49
10	-8.010	145
20	-5.867	106.64
30	-5.411	98.35
40	-5.14	93.466

Table (4) estimation values of lifetime of PVC doors based on a mass loss of 30% at different temperatures

doors	Lifetime (years) at temperature		
	60 ˚C	70 ˚C	80 ˚C
Firat	137.15	71.97	23.71
Nova	45.41	20.56	4.54

Table (5) T_g and T_s values of Firat and Nova

NO.	Specimen	T_g (C˚)	T_s (C˚)
3	Firat	65.64	66.62
4	Nova	65.23	66.17

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الخلاصة:

في هذا البحث تم دراسة الخواص الميكانيكية والحرارية والميكانيكية الحرارية وكـذلك عمر الأداء لشركتين تركيتين لإنتاج الأبواب. ولهذا الغـرض أجريـت لهـا مجموعـة مـن الاختبارات شملت اختبار الشد والإنحناء والصدمة والصلادة والتوصيلية الحراريـة والقيـاس الوزني الحراري (TGA) وكذلك الاختبار الميكانيكي الحراري (TMA).

من خلال منحنيات (TGA) تم تحديد طاقة التنشيط والإتزان الحـراري وعمـر الأداء بوساطة معدلات تسخين مختلفة (٢، ٥، ١٠، ٢٠، ٤٠ °C/min)، بينما درجة حرارة التحـول الزجاجي ونقطة الليونة تم تحديدها من خلال منحنيات (TMA).

أظهرت النتائج أن شركة الفرات تتغلب على النوفا في الخواص التاليـة :(الميكانيكيـة، التوصيلية الحرارية، الإتزان الحراري، عمر الأداء)، بينما درجة حرارة التحول الزجاجي (T_g) ونقطة الليونة (T_s) تكون متساوية لكلا الشركتين تقريباً.