Studing The Mechanical Properties And Morphology of Ternary Blends Of Polyethylene

Nabeela A. Mohammed*

Abstract

The mechanical properties and the morphology of the ternary blend of LDPE/LLDPE/HDPE were studied.

In the present work LDPE was mixed with equal amount of LLDPE and different wt% of HDPE (0, 10, 20 and 30 %) using the two roll mills. The mechanical properties and the morphology were specified by measuring the (tensile, hardness, impact properties) for the former, and photomicrograph for the later. From the tensile test results it was found that the tensile strength at break of the ternary blend increased with increasing the HDPE contain also the increases of wt% HDPE leads to decrease the elongation at break. For the hardness test it was found that the shore hardness of the ternary blends increased with the increasing the HDPE contain .On the other hand the impact test carried out also and it was found that the addition of HDPE leads to decrease the impact strength . Nevertheless, optical micrograph results that the HDPE serves as a compatabilizing agent for immiscible LDPE/LLDPE.

Keywords: ternary blends LDPE/LLDPE/HDPE, mechanical properties.

دراسة الخواص الفيزياوية والبنية الشكلية لممزوجات ثلاثية من البولي اثيلين

الخلاصة

في البحث الحالي قد تم درسة الخواص الميكانيكيه والبنيه الشكليه لممزوجات ثلاثيه المواد من البولي اثيلين واطىء الكثافه / البولي اثيلين واطىء الكثافه الخطي/ البولي اثيلين عالي الكثافه (LDPE/LLDPE/HDPE).

تم استخدام ثلاث انواع من البولي اثيلين, فقد تم مزج البولي اثيلين الواطىء الكثافه مع كميه متساويه من البولي في البحث الحالي قد تم دراسه اثيلين الواطىء الكثافه الخطي وقد تم اضافه نسب وزنيه مختلفه من البولي اثيلين عالي الكثافه (0,10,20,30%) وذلك باستخدام الاسطوانات المدلفنه لهذا الغرض.

تم تعيين   الخواص الميكانيكيه والبنيه الشكليه وذلك بقياس (الشد, الصلاده وخواص الصدم) والتصوير المجهري ,من نتائج اختبار الشد وجد بأن الاجهاد عند نقطه الكسر يزداد بزياده محتوى البولي اثيلين عالي الكثافه في الممزوجات , ايظا زياده نسبه البولي اثيلين عالي الكثافه ادى الى تقليل النسبه المئويه للاستطاله عند نقطه الكسر . بالنسبه الى فحص الصلاده وجد بأن قيم صلاده شور تزداد بزياده محتوى البولي اثيلين عالي الكثافه , من ناحيه اخرى تم اجراء فحص الصدم وقد وجد بأن اضافه البولي اثيلين عالي الكثافه ادى الى تقليل اجهاد الصدم , ومن نتائج التصوير المجهري يتضح جلياً بأن البولي اثيلين عالي الكثافه ساعد على زياده امتزاجيه الخليط الثنائي الغير ممتزج من البولي واطىء اثيلين واطىء الكثافه/ البولي اثيلين واطىء الكثافه الخطي .

1. Introduction

Polymer blends and composites are widely used in as an industrial product, where different polymers are blended to combine the positive attributes of each component polymer (i.e. impact strength, rigidity, chemical resistance, etc.) [1]. Over the last two decades the interest in polymer blend systems as a way to meet new market applications with minimum development cost has rapidly increased. This approach has not been achieved without its difficulties and has developed as rapidly as it might have, in part because most physical blends of different high molecular weight polymers prove to be immiscible. That is, when mixed together, the blend components are likely to separate into phase containing predominantly their own kind. This

*Chemical Engineering Department, University of Technology/Baghdad

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characteristic, combined with the often-low physical attraction forces across the phase boundaries, usually causes immiscible blends system to have poor mechanical properties [2, 3]. The resulting mechanical properties of the polymer system are highly dependent on the morphology obtained [4].

It is possible to study ternary systems where a suitable third component is added in relatively small amount to the previously considered bicomponent materials to increase the compatibility of their constituents or at least to improve the homogeneity of the material. Generally these additives are some copolymers, whose chemical sequences are made by the same monomers of the two polymers of the primary bicomponent material [5].

Polyethylene – Polyethylene blend has been a topic of great academic and commercial interest for the past decade, owing to its relevancy to the understanding of processing and performance properties of blends containing different types of polyethylenes. With this background, a number of studies on polyethylene – polyethylene blends, for example low – density polyethylene / linear – low-density polyethylene blends have been published. Acierno et.al. [6] compared the ultimate tensile properties and dart impact behaviour of co-extruded film of LDPE and LLDPE with those of films made from blends of the same resins. The results indicate that, at least for semi-compatible systems like that considered here, films made from blend and co-extruded ones have mechanical properties very close to each other.

Melting and crystallization of several binary polyethylene blends were studied by Ree et.al. [7] under the isothermal condition LDPE blended either with HDPE or LLDPE crystallized separately .

Kyucheol et.al. [8] have studied the rheological and mechanical properties in linear low density polyethylene (LLDPE)/low density polyethylene (LDPE), LLDPE/high density polyethylene (HDPE), and HDPE/LDPE blends, and they found that all three blends were miscible in the melt, but the LLDPE/LDPE and HDPE/LDPE blends exhibited two crystallization and melting temperatures melt. The melt strength of the blends increased with increasing molecular weight of the LDPE that was used. The mechanical properties of the LLDPE/LDPE blend were higher than calculated from a simple rule of mixtures, while those of the LLDPE/HDPE blend conformed to the rule of mixtures, but the properties of HDPE/LDPE were less than the rule of mixtures prediction.

Heon Sang and Morton [9] studied the ternary blends containing a critical concentration of HDPE and they found a single melting peak.

Heon et.al. [10] have studied rheological and thermal properties of the LLDPE/LDPE blends, the results on binary systems suggest the use of HDPE as a compatibilizer for LLDPE/LDPE blends, apparently creating a fully miscible ternary system.

Blends of LLDPE and LDPE have been reported immiscible or partially miscible by Hussein and Williams [11].

Deepak et.al. [12] studied thermo-oxidative degradation of ternary blends of polyethylene. Film of low – density polyethylene (LDPE) and high – density polyethylene (HDPE) each containing 25wt% of linear low – density polyethylene (LLDPE) were extruded by melt blending in a single screw extruder.

In this study, the changes in mechanical properties (tensile, impact and hardness properties) of blends of linear low – density polyethylene, LLDPE, with low – density polyethylene LDPE, after adding various amount of high – density polyethylene, HDPE, as a compatabilizing are investigated.

2. Experiment
2.1 Materials
The net polymers used in this study are a commercial low – density

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polyethylene, LDPE, a commercially linear – low-density polyethylene, LLDPE type 21018(461) , and high – density polyethylene, HDPE type (EHM6003). Thermoplastic resins used in present work were locally manufactured in Petrochemical Complex (Basrah-Iraq). The important characteristics of the materials are given in table 1.

2.2 Mixing and preparation of the samples

This process involves mixing equal wt% of low – density polyethylene and linear low – density polyethylene with different wt% of high – density polyethylene (0, 10, 20, and 30) % using the two roll mills which consist of robust horizontal cylindrical polished rolls channels, the rolls counter rotates and the channels are separated by a narrow gap called the "nip". The feed is dropped directly in between the two rolls. The sticky mass is dragged down from the rolling reservoir into the nip and adheres as a band on to one of the rolls, the band then can be cut and it is simply folded over [13].

The mixing machine is operated at a temperature of 190 ^{o}C and at speed approximately 10 mm/min. The compounding time involved ranged between (2-5 min). The mixing machine used for this purpose a roll mill poly mix. 150P.

The pressing method is used in this research for pressing the prepare blends after mixing them, the applied pressure was (10Mpa) and the temperature was (190 ^{o}C). The CININNATI hydraulic press was used for this purpose with maximum load (15 ton), the mixing machine and hydraulic press available in the National Company for Chemical and Plastic Industries in Baghdad.

2.3 Measurement of mechanical properties

The mechanical properties were specified by measuring the (tensile, impact properties, and shore hardness).

2.3.1 Tensile test

Tensile test, in a broad sense, is a measure of the ability of a material to withstand forces that tend to pull it apart. The familiar dog-bone shape was utilized in the testing procedure; this type specimen was the preferred specimen and should be used where sufficient material having a thickness of 4 mm or less is available. An Zwick testing machine type (1431) was used to perform the tensile strength test at a crosshead speed of 50 mm/min as described in ASTM procedure D638, (ASTM 1999), and each test was performed until tensile failure occurred. The load at the point of fracture value (force) was recorded by the instrument, which can be recalled after the completion of the test. Also the elongation was measured (the extension of the sample at breaking point) [14].

2.3.2 Impact test

The charpy impact test measures the energy absorbed by the high strain rate fracture of a standard notched specimen. The specimen is broken by the impact of a heavy pendulum hammer, falling through a fixed distance (constant potential energy) to strike the specimen at a fixed velocity (constant kinetic energy). Tough materials absorb a lot of energy when fractured and brittle materials absorb very little energy. In this work the impact resistance was determined using Charpy impact test instrument No – 43 – 1, made by Testing Machines, Inc. Test specimens were used in present work according to the test specification of ASTM (D256 – 87) samples were notched (1 mm depth) by using Ceast notch instrument. The notch specimen was supported as a simple beam by two anvils and the swinging pendulum strikes behind the notch on the unnotched side of the test specimen [14, 15].

2.3.3 Hardness test

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation, indentation, or scratching. Two types of Durometers are

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most commonly used type A and type D. Due to the slightly harder sample being examined; the Durometer hardness tester shore instrument Zwick type D-2240 was used. Durometer readings were taken according to Iso-868. The Durometer hardness was read within 1 sec after the pressure foot was in firm contact with the specimen. Each specimen was subjected to 10 Durometer hardness readings, at designated positions on the sample bases. Values for these readings were then averaged.

2.4 Morphology evaluation

The morphology evaluation was carried out using an optical microscope Nikon 540x. A small specimen was cut from the molded film of the LDPE/LLDPE/HDPE blends at different ratio of HDPE.

3. Results and Discussion

3.1 Tensile tests

Stress-strain curves of LDPE/LLDPE/HDPE blends depends on the morphology, tensile stress (strength) at break may be defined as the tensile stress at moment that test piece destroyed [5, 13].

$$Stress = F / A \ldots (1)$$

where: F=Force applied in (N)

A = original area (mm^2)

Figure (1) show the tensile strength at break of LDPE/LLDPE/HDPE blends as a function of wt% HDPE , the tensile strength at break of the ternary blends containing (0-30) weight percent of HDPE increase with increasing HDPE content , the increase in the tensile strength at break can be explained by better adhesion between HDPE phase and LDPE/LLDPE blends and thus by an increase of effective load bearing cross section .These large effects indicate again that HDPE must be present at the interface between LDPE and LLDPE.

Elongation at break is the elongation which corresponds to tensile breaking strength. It is expressed in terms of the percentage of the original length [13, 16].

$$Elongation\,(\%) = \frac{L - Lo}{Lo}\, x100 \ldots (.2)$$

where : L = extensional at breaking point.

Lo = original length

Figure (2) show the % elongation at break of LDPE/LLDPE/HDPE blends as a function of HDPE content. From this figure it is clear that the increase of wt% HDPE in LDPE/LLDPE blends leads to decrease the % elongation at break because the addition of HDPE causes a decrease in the elasticity which leads to decrease the % elongation at break.

3.2 Impact test

Impact resistance is the ability of a material to resist breaking under a shock loading or the ability to resist fracture under stress applied at high speed. Impact properties of the polymeric material are directly related to the overall toughness of the material .Toughness is defined as the ability of the polymer to absorb applied energy [17].

Fracture energy calculated by using this equation:

$$impact \;\; strength = \frac{fracture \;\; energy \;\; required}{cross \; \sec tion \;\; area \;\; of \;\; the \;\; sample}$$

(3)

The unit of the impact strength is Joule/ m^2.

Figure (3) show the impact strength of LDPE/LLDPE/HDPE blends as a function of HDPE content. From this figure it is clearly seen, that the increasing of the HDPE content causes an decrease in the impact strength, the presence of the HDPE which is hard in a soft ,tough LDPE/LLDPE blends suffice to decrease the impact strength , i.e. to give it the character of a hard ,resistance material. The strength of the matrix, the

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weakest part of the material, should relate to the failure process. The total energy dissipated in the polymeric material before final failure occurs is a measure of its impact resistance.

3.3 Hardness test

The hardness of plastics was measured by the Shore (Durometer) test. This method measures the resistance of plastics to indentation and provides an empirical hardness value that does not correlate well to other properties or fundamental characteristics. The hardness value is determined by the penetration of the Durometer indenter foot into the sample. The results obtained from this test are a useful measure of relative resistance to indentation of various grades of polymers. Ten readings were taken for each specimen, as material properties were expected to vary with location on the sample.

Figure (4) show the hardness as a function of wt% HDPE for the LDPE/LLDPE/HDPE blends, from this figure it is clearly seen that increasing the HDPE content leads to an increase in the shore hardness, this may be due to the fact that the hardness is generally considered to be a property of the surface therefore this behaviour of hardness is expected. The addition of the HDPE leads to a decrease in the elasticity and an increase in the matrix surface resistance to the indentation.

3.4 Morphology

Blends of LDPE /LLDPE/HDPE containing (0,10,20,30) %wt of HDPE has been examined with scanning electron microscopy .The micrograph (fig.5a) shows a structure consisting of LDPE/LLDPE blends that the two phases seem to penetrate one in to other. Figures (5b, 5c, 5d) show the LDPE/LLDPE/HDPE blends at different HDPE contain, from these figures it is clearly seen that HDPE serves as a compatabilizing agent for immiscible LDPE/LLDPE blends, reducing the surface tension of the two polymers that leads to an extremely fine dispersion of one phase in the other and increasing

their interfacial adhesion, giving improved stress transfer [18].

4.Conclusions

Blends of LDPE/LLDPE/HDPE have been studied, the tensile test results obtained in this work show that the tensile strength at break of the ternary blends increase with increasing the weight percent of HDPE. Also from the results presented here indicate that the % elongation at break decrease with increasing the HDPE content .The impact strength of the polymeric material decrease with increasing HDPE content that the HDPE which is hard in a soft ,tough LDPE/LLDPE blends suffices to decrease the impact strength .Also shore hardness values were observed to be increase with increasing the weight percent of HDPE .Furthermore, optical micrograph results showed that the HDPE serves as a compatabilizing agent for immiscible LDPE/LLDPE blends , reducing the surface tension of the two polymers that leads to an extremely fine dispersion of one phase in the other and increasing their interfacial adhesion.

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Table (1) Characteristics of neat polymers

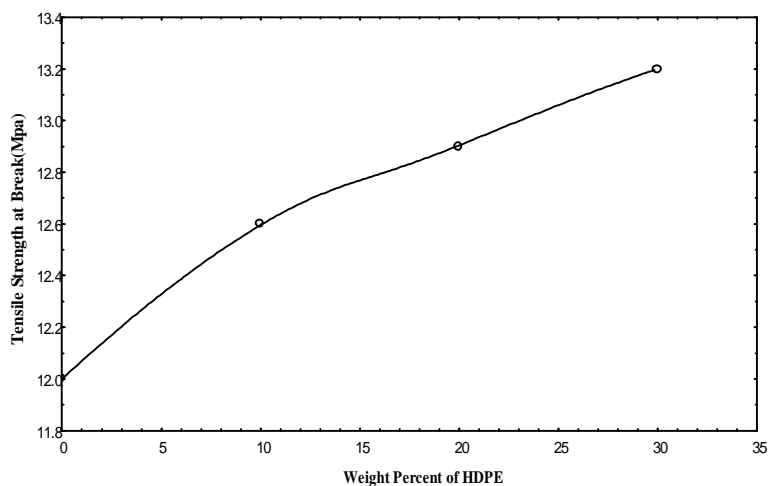| Property	LDPE	LLDPE	HDPE
DENSITY (g/cm³)	0.923	0.94	0.963
MELTING FLOW INDEX(g/10 min)	7	2	0.36

**Figure (1) Tensile strength at break of LDPE/LLDPE/HDPE blends
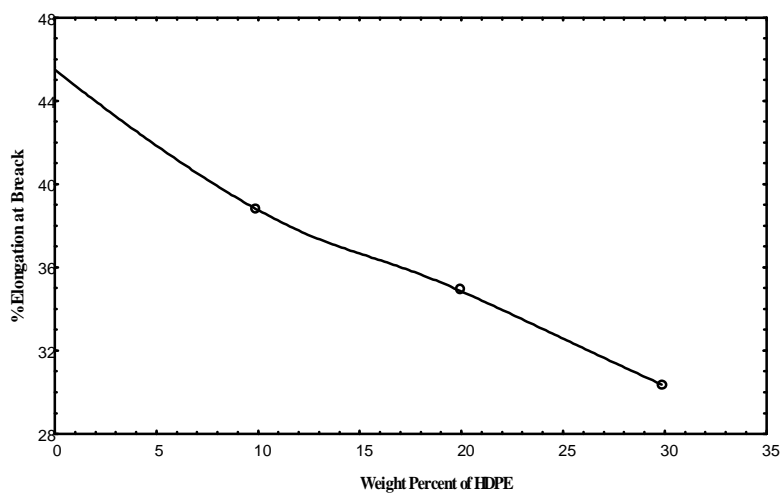as a function of HDPE content (wt %).**

**Figure (2) % Elongation at break of LDPE/LLDPE/HDPE blends
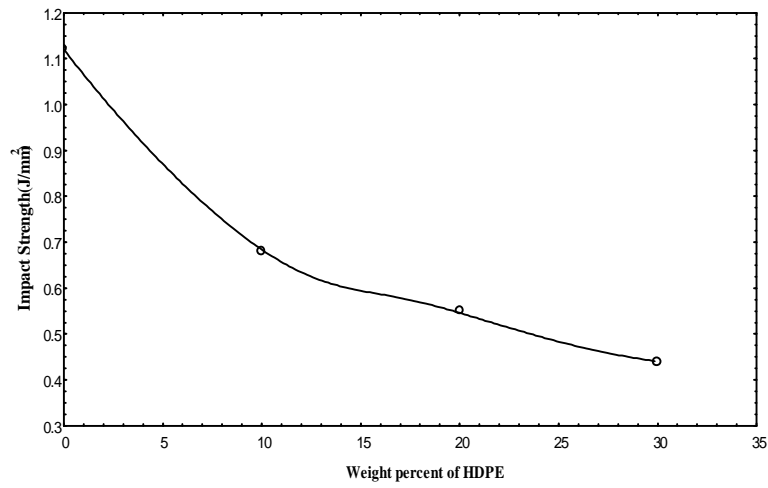as a function of HDPE contents (wt %).**

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**Figure (3) Impact strength of LDPE/LLDPE/HDPE blends
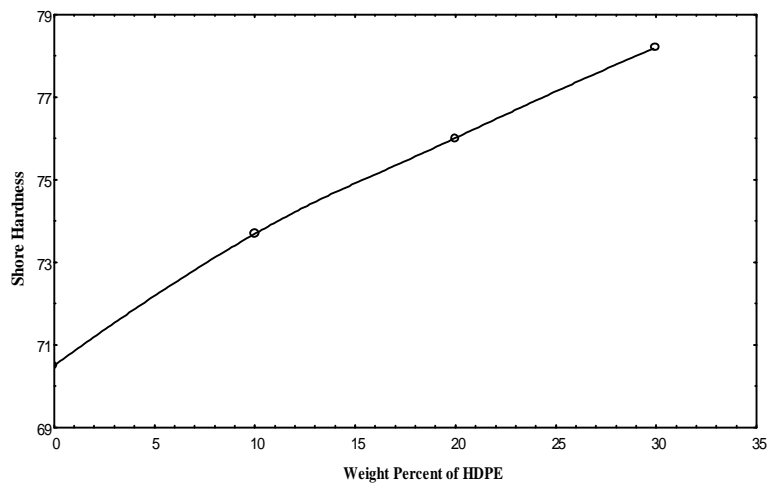as a function of HDPE contents (wt%).**

**Figure (4)   Shore hardness of LDPE/LLDPE/HDPE blends
as a function of HDPE contents (wt %).**

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(b)   (a)

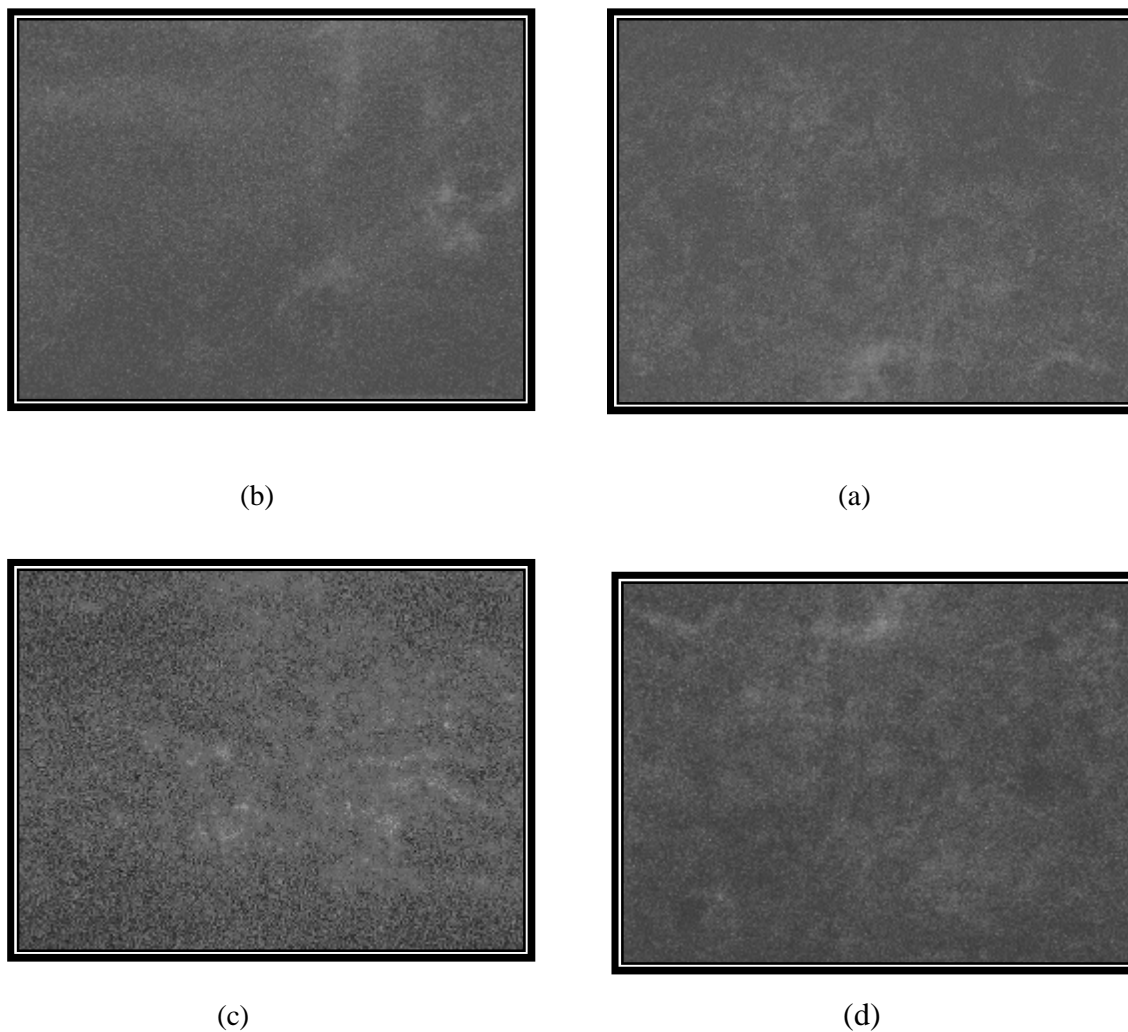(c)   (d)

**Figure (5)   Micrographs of LDPE/LLDPE/HDPE blend with (a) 0 % HDPE (b) 10%
HDPE content (c) 20% HDPE content and (d) 30% HDPE content.**

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