Optimizing the Conditions for the PVC Playing- Balls Fabrication

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Abstract

Although PVC polymer is one of the cheapest plastics that are widely used in industry. The conditions of PVC processing industries are still industrially and commercially confidential and uncovering it is still industrially and commercially confidential and uncovering it is not easy.

This work aims to make processing conditions available to whom interest. This has been achieved by studying the parameters associated with production process and determine the optimum conditions which are necessary to get best quality and more economical product. These parameters are included:

1- Mixing equal quantities of both rigid and flexible PVC will give requiredhardness for product with degree of polymerization 600-700.

2- Addition of 3% stabilizer (tribasic lead sulfate) works on raising temp. Of process to 250 centigrade without polymer burning or dissociation.

3- Addition of 55% plasticizer (dioctyl phthalate) to polymer (melting point of polymer T_m = 90-100 centigrade and glass transition temp. T_g = 170 C^o) decreases T_g below room temp. 20-25C^o .As a result of this work, product has enough strength and good flexibility to charge with required volume of air.

4- Coloring of product by 2% Titanium oxide to give bright white color.

Oven temp. Is 150-180 C^o.

Keywords: PVC,Polymer processing,Stabilizer,Plasticizer

تحديد الظروف المثلى لأستخدام بوليمر كلوريد الفنيل في تصنيع كرات اللعب

الخلاصة

على الرغم من كون بوليمر PVC من أرخص المواد وأكثرها أستخداما في الصناعة , الا أن الظروف المحيطة بعملية التصنيع لا تزال سرية صناعيا وتجاريا والكشف عنها ليس بالشيء اليسير.

يهدف هذا البحث الى جعل ظروف التصنيع التي تم التوصل اليها عملية متاحة وبالامكان الاطلاع عليها والاستفادة منها عمليا ..يتم ذلك من خلال دراسة المتغيرات المرافقة لعملية التصنيع وتحديد الظروف المثلى لتحقيق جودة المنتج وجدواه الاقتصادية , وقد شملت هذه المتغيرات :

1. نوعية بوليمرات PVCالمستخدمة ونسبة خلطها وقد وجد أن أستخدام خليط متساوي المقادير من كل من PVC الصلب وPVCاللدن يحقق مواصفات وسط بين الصلابة واللدونة للبوليمر المستخدم وبدرجة بلمرة تراوحت بين600-700 لتوفير القوة المطلوبة للمنتج .
2. نسبة المثبت (كبريتات الرصاص ثلاثية القاعدية) والذي يعمل على رفع درجة حرارة التصنيع بدون أن يتفكك تركيب البوليمر أو يحترق وبالتالي تتغير مواصفاته . ونسبة

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مثبت 3% من الخليط حققت المطلوب ورفعت أمكانية التصنيع بدرجة حرارة حتى 250درجة مئوية.

3. إضافة الملدن (ثنائي أوكتيل الفثالات) الى خليط البوليمر (درجة أنصهارالبوليمر Tmحوالي 90- 100ودرجة التحول الزجاجي Tg حوالي 170 درجة مئوية) ساعد على خفض Tgالى درجة أقل من درجة حرارة الغرفة حوالي 25درجة مئوية . هذا ماجعل خليط البوليمر مرن في درجة حرارة الغرفة بعد أخراجه من الفرن وتبريده وبالتالي سهولة ضخ الكمية المطلوبة من الهواء في منتج كرات اللعب ومن ثم تفريغها أستعدادا للشحن . وصلت نسبة اللملدن الى 55% خلافا لما هو متعارف في الأدبيات بنسبة 30% .
4. اللون الممثل بأوكسيد التيتانيوم بنسبة 2% لأعطاء اللون الأبيض البراق وتسهيل التلوين بمختلف الألوان لاحقا.درجة حرارة الفرن وتراوحت بين 150-180 درجة مئوية .

Introduction

The fact that PVC has become a high volume plastic, (≈ 30million tons per year produced in 2002) [1,9],is attribute chemical innovation depending on the additives used, PVC can be made a rigid or highly flexible [2]. The mechanical properties of PVC can be modified through the addition of plasticizers that mix well with the polymer matrix [3].Also the stabilizers are added to the PVC polymer to prevent degradation [4].

The development of PVC illustrates the interplay of logic and serendipity, as well as the importance of optimizing properties

both for processing and for applications. PVC production has been beset with difficulties from the beginning, but solutions have been found for each problem through a combination of chemical deduction and trial and error [2].

Experimental Operating System

Production line of balls and toys (Cacio Company, Italy) consists of:

1-main mixer: it is a stainless steed tank with an internal starrier and an air value to take out the material with the starrier is operated by an electric motor of (3 H.P).

2-mold packing tank: it is of a 30L capacity with an external starrier which is operated by an electric motor of 0.5H.P. This tank processes an air valve for packing molds only.

3-the molds are beard by a system consists of three arms, each arm has a 36 molds.

Inside the oven, this system is rotated in the xy-plane by a hydrolic motor every 20 minutes each molds arm enters the oven individually.

4-the oven: it contains 30 heaters (three-phases heaters) of 3000A for each, besides that the oven is supplied with an air pump is to pass air over the heaters inside the oven.

5-cooling part: the molds are cooled directly by two ways :

a. water with compressed air for 2minutes.

b. air spray for 15minutes.

Chemical Materials

rigid PVC (suspension sabic, K.S.A), flexible PVC (emulsion, Iran), di-octyl phthalate (DOP, Iran), [$(PbO)_3.PbSO_4$] tribasic lead sulfate

(Germany), (TiO_2) titanium oxide (Germany).

Operation Conditions

In mixer, required quantities of DOP and TiO_2 mixed for five minutes. Then flexible PVC was added to them and mixing for 30 min.

At last the addition of rigid PVC to a mixture above and mixing for 2 hours would be necessary to prepare PVC for processing [5]. The second step included mixing PVC with it's additives again for 10 min. in sub mixer to prepare it for injection in moulds. PVC would processing in oven for 20 min. for the same time in cooler and empty or recharge part. Blowing moulds and painting the final product of PVC ball would be the final works.

Results and Discussion

Resin selection:

PVC resins are usually categorized on the basis of molecular weight (in other words degree of polymerization). D.P of pvc is 300-1300. The minimum range 300-600 is for flexible pvc , therefore it's melt viscosity and hardness are low. In oppose to flexible , rigid pvc has 800-1300(as d.p.) and good strength .The importance of molecular weight in determining PVC properties can be appreciated by understanding how this parameter is controlled and its influence on important physical properties [6,11].

Figures (a,b) explain the effect of molecular weight on properties of polymer [13,6] .

Two main processes are used to produce PVC suspension polymerization (80%) and emulsion polymerization (10%).The main distinction between the numerous application is between (rigid PVC) and (flexible PVC) (1). 50% of each flexible (emulsion) PVC and rigid (suspension) PVC were employed in processing method to get required hardness.

An addition of appropriate quantities of additives, PVC would be easily compounded, injection molding thermoforming and blow molding [7]. PVC is compounded [8] by addition of:

1-Thermal Stabilizer

Approximately 3% of lead oxide is suitable stabilizer in this PVC processing addition of stabilizer is necessary because the temperature where PVC begins to flow sufficiently to allow fabrication is close to that where thermal degradation begins, thermal stabilizer is essential to reduce the amount of dehydrogenation of PVC chains or react with HCl which is the product from thermal degradation of the molecules [1, 3, 10].

Without addition stabilizer, PVC burned at 100^oC with stabilizer, temperature of processing increases to be more than 250^oC.

The thermal stability of PVC decreases with decreasing average M.wt, so far high flow applications, the thermal stabilizer is sometimes needed at high levels in comparison with rigid PVC.

Lead oxide acts as weak base, reacting with any released HCl from degradation of pvc, which is basically colorless turn deep yellow, orange, brown or black, depending on the degradation degree.

This thermal stabilizer is usually used to provide the balance of properties needed to avoid color formation viscosity increment, volatiles formation and catastrophic chain

degradation within the processing conditions of a given formation [6].

2-Plasticizer

The function of a plasticizer is to yield a more flexible, extendible and workable formulation and finished product [14]. The mechanism is in it's simplest terms, to provide a solvent for the polymer molecules which is low volatility and low extractability.

The quantities of plasticizer added to the PVC polymer vary depending on required properties and on the final use [3].Plasticizers are necessary in large amount to manufacture flexible PVC while rigid PVC needs less concentration of plasticizer [7].

DOP (dioctylphthalate) is one of the most common plasticizer which is used in processing PVC. In this search an appropriate ratio of DOP to PVC was found to be 1.25:1 (55%).

In fig2.1, it is noticed that using a low density PVC leads to very determined ability of formulation with addition small quantity of DOP.

Fig.2.2 high density PVC needs more quantity of DOP to increase formulation ability but the product still does not have the required elasticity to take the needed volume of air when it pumps.

Fig.2.3 equal weight of high density and low density PVC with DOP at 1:1.25 will be easily to formulate and has ideal elasticity to form the final product.

Fig 2.5 shows that mixing equal quantities of rigid PVC with 55%DOP will be easily to take mold shape with whole diameter (sink) after pumping air in product. Below 55% DOP, ball has bombed before it takes required air volume because of high polymer hardness above 55% DOP, ball has expanded out of mold after it pumped air, because of high polymer flexibility.

3-Pigment

Metal Oxides are among durable pigments for PVC, giving excellent color retention, stability and resistance to migration. The most common example of this glass is titanium oxide (TiO_2) [2].

TiO_2 is white pigment, good for weathering, high brightness and high tint strength [3]. It is also used as UV light absorber to protect against damage from sun light 2% TiO_2 of PVC is the best and more economic percentage to produce finest product.

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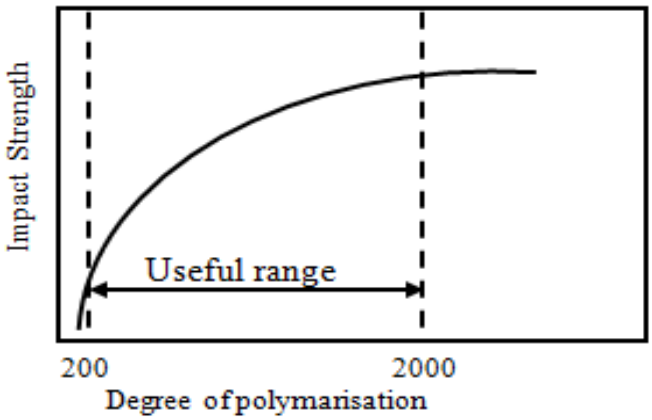


Figure (a) Dependence of impact strength of a polymer on degree of polymerization.

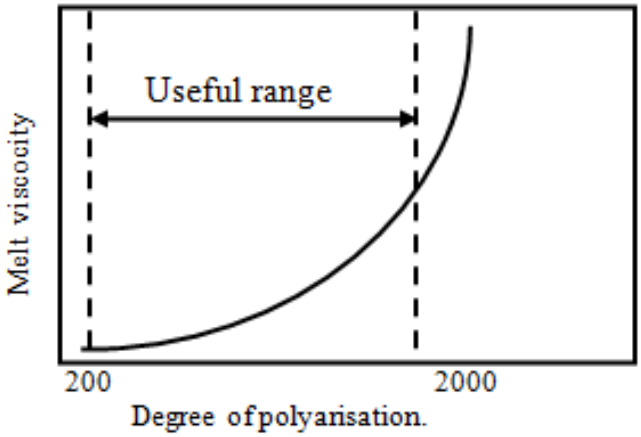


Figure (b)Dependence of melt viscosity of a polymer on degree of polymerization.

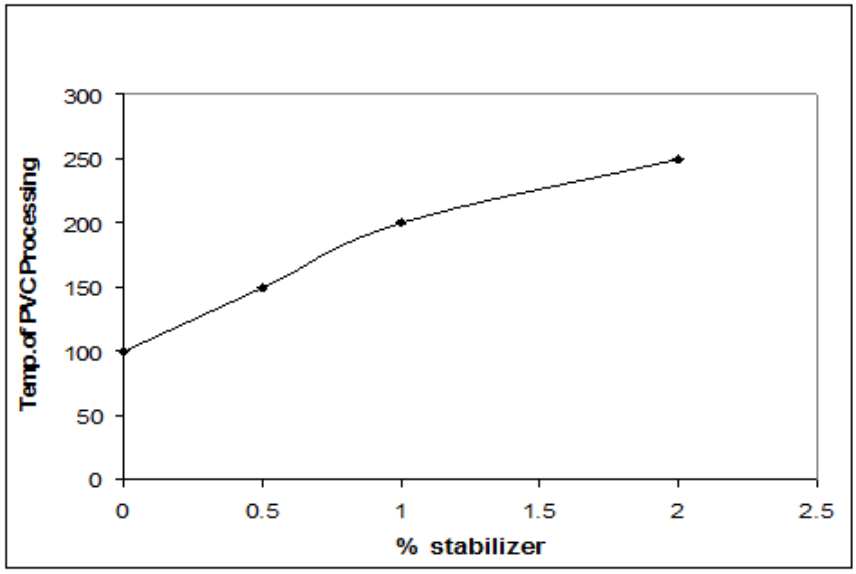


Figure (1) Dependence of processing temp. on quantity of added stabilizer.

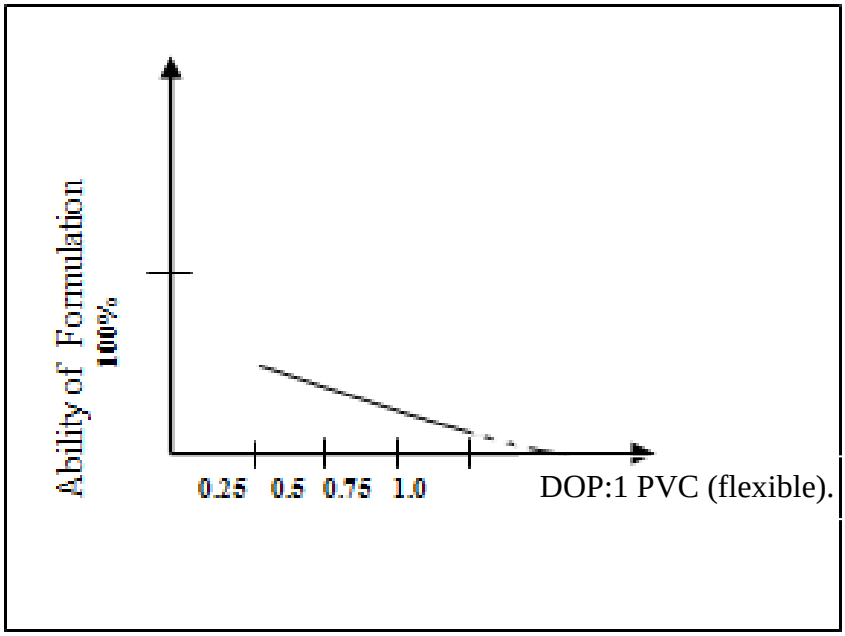
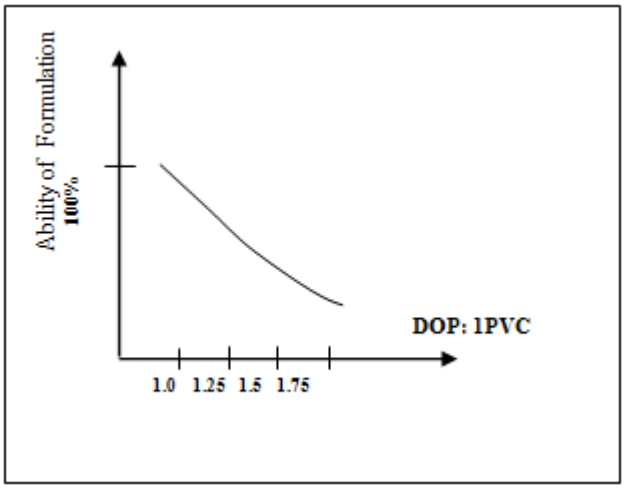
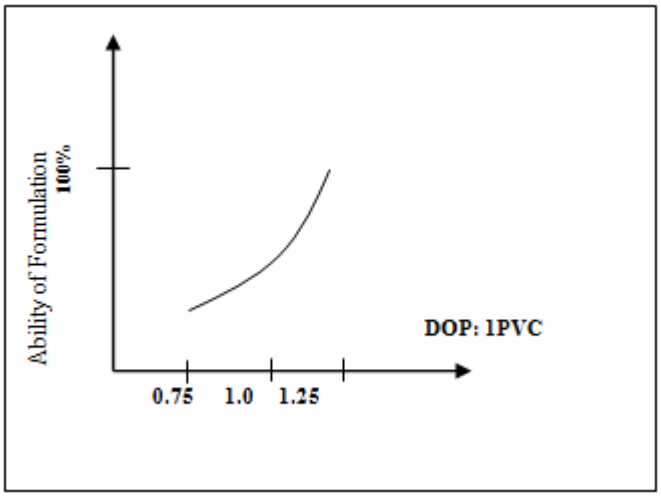


Figure (2.1) low density PVC have very determined ability of formulation



Figure(2.2) (rigid) PVC needs more quantity of DOP to increase formulation ability



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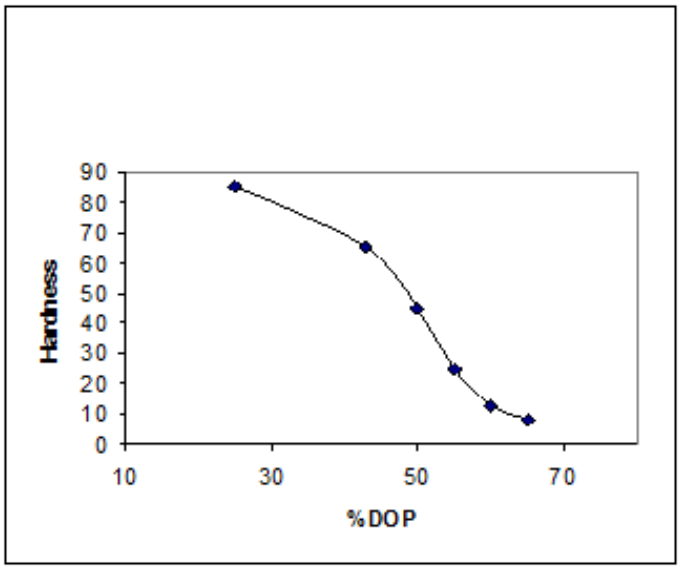

Figure (2.4) effect of addition DOP on hardness of polymer product.

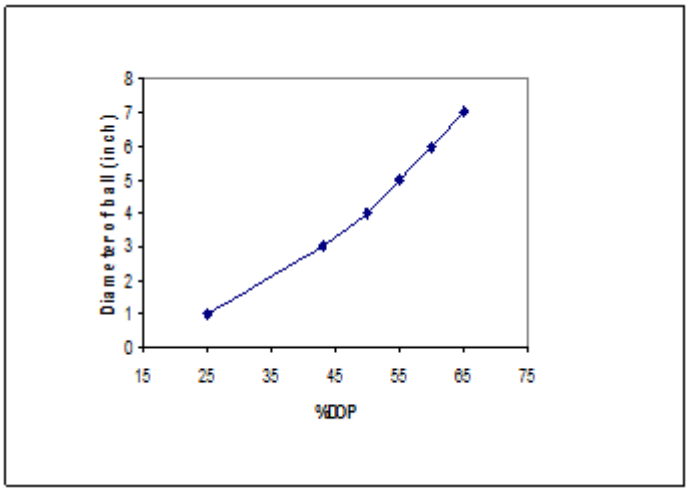

Figure (2.5) effect of addition DOP on diameter of balls product.