COMPONENTS OF PATTERN MATERIALS AND ITS INFLUENCE ON PHYSICAL PROPERTIES

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ABSTRACT

Pattern material that used in investment casting process was studied. Physical properties such as melting point, congealing point, penetration, viscosity, linear shrinkage and ash content were investigated. Pattern materials were prepared using paraffin wax, Carnaubea wax (vegetable wax), dammar (natural resin) and filler of Pentaerythritol. The results indicated that each component was influencing all the studied physical properties.

INTRODUCTION

Pattern materials are compounds of many component has been included to influence final properties of pattern material are of critical importance to the foundry in the production of good castings.

Mixing different types of waxes, resins and filler materials were used to prepare pattern material, which was used, for including different US patents. These patents indicated the raw materials and their weight percentages were not available locally. One important condition is that the mixture must be compatible both in the liquid and the solid phase. Therefore mixing conditions such as mixing temperature, mixing speed and time of mixing should be accurately chosen to ensure the compatibility of the phases. In order to obtain high quality material physical properties, namely melting point, congealing point, penetration, viscosity, ash content and linear shrinkage, should be evaluated and compared with standard specification of pattern materials produced by different companies such as Oastylene wax B-289 (British Investment Casting Trade Association (BICTA) and KBF-595 (Subnex Copany.)these physical measurements are important and have a significant effect on investment casting process.

Melting and congealing point are required injection temperature of liquefied pattern material in the injection machine. Suitable penetration values are required to obtain unbreakable samples without pending. Viscosity is important to ensure that the liquefied pattern material evenly distributed in the die as wall as in determining the required in the injection machine. The ash content should be in a minor quantity to prevent distortion of the final cast. Linear shrinkage should be determined since it plays a major role on the dimension of the final cast.

General Properties and Quality of Pattern Materials

Melting and congealing points

Melting point is the temperature at which a drop of the sample detaches itself from the main bulk. While congealing point, or setting point, is that temperature at which molten sample, when allowed to cool under prescribed congealing, ceases to flow. Since the melting point is closely allied to the congealing point test, it is reasonable to deal with them together.

Melting and congealing point have a major influence on the required injection temperature of the pattern material in wax injection machine. Pattern material passes through a number of phases on heating or cooling. Congealing and melting point will represent temperatures at the beginning and the end of semi-liquid state respectively [1,2].

Ash content

Ash content represents the percentage of non-combustible solids contained in the pattern material. That could take place on the surface of the final castings [1,3].

Penetration

Penetration is the distance in tenths of millimeter that a standard needle penetrates vertically into a sample of pattern material under fixed condition of loading time and temperature.

Penetration gives a guide to the hardness of pattern material. It is necessary that the pattern material have sufficient hardness and elasticity in order to reduce the possibility of rejects due to breakage, bending or other undesirable phenomena during pattern processing [1,4].

Kinematic viscosity

Kinematics viscosity is amasser of time for a fixed volume of liquid to flow through a capillary; it is usually expressed in cent-stoke (CST). Dynamic viscosity is a numerically the product of kinematics viscosity and the density of the liquid at the same temperature. The unit of dynamic viscosity is the poise (g/cm. s). For Newtonian fluids, the dynamic viscosity as a quantitative measure of the tendency of a fluid to resist shear. The viscosity of pattern material is critical to successful pattern production. The results of viscosity test give a guide to the flowability of the liquefied pattern material. The pressure required to transfer pattern material from wax injection machine to the die and the size of the injection channel required to maintain pressure required[1,5].

Linear shrinkage

Linear shrinkage of the pattern material should be obtained as one value at 25°C since the dies were designed in one specific dimensions, in order to get final casting with fixed dimensions. The shrinkage of pattern material, when cooled will facilitate easy removal of the pattern from the die.

Compatibility

Compatibility is the ability of two or more substances to mix with each other in order to form a homogenous solution that has useful properties. Compatibility can be related to wax-resin system. Compatibility is therefore the solubility in which wax behaves as a solvent for the resin. Wax, which is highly compatible with one type of resin, may not be at all compatible with another type of resin-Heating sometimes may give compatibility for the wax-resin mixture provided the temperature of mixing is not exceeding degradation temperature of any component in the mixture. There are methods depending on the structure of wax and resin in which solubility parameter (S) were evaluated using available thermodynamic data. Solubility parameter depends on the composition of the components in the mixture and their weight percentages. Compatibility is established when there are complete homogenous solution with no color change, no precipitation, no flotation, no turbidity and no phase separation ^'718). That is a complete homogenous mixture equally distributed between the solute and the solvent at that temperature. The suitability of pattern material should be based on two concepts:

1. The compatibility of waxes and resins with each other.
2. The incompatibility of waxes-resins mixture with the used filler.

EXPERIMENTAL WORK

The apparatus used for all experiments were made up from 400-ml beaker,, heating mantle, which was connected to a voltage regulator in order to adjust the heating temperature. This heating mantle was covered with a glass wool to reduce heating losses. A multi speed mixer with a stainless steel cross shape impeller was used for agitation. Digital thermometer with a suitable heat sensor was used to measure the temperature of the mixture inside the beaker. The used apparatus is shown in Fig. (1).

Procedure for Preparation of Pattern Material

Preparation of pattern material was achieved by five stages namely; melting and heating of waxes-resins mixture, mixing with heating, addition of the solid filler particles during mixing, casting and cooling. Fig. (2) shows a schematic diagram of-the preparation.

In each experiment, waxes and resins were melted and heated till they reach the desired mixing temperature (120 °C). The heating of the above mixture was achieved at a rate of 1°C/minute with slow agitation to prevent overheating -and decomposition of raw materials. Then the stirrer was switched on to the desired mixing speed (1500-rpm). This mixing speed was kept constant during the desired time of mixing (15 minutes) by means of speed controller to maintain homogeneous single liquid phase. After a period of time from stirring, solid filler particles were added to the mixture of waxes and resins. The time required *for* adding the filler was about 10 minutes in order to prevent sudden decrease in temperature and also to ensure complete distribution of the solid filler particles. Mixing was continued for a period of time (15 minutes). Later the blend was poured into an aluminum die having a fixed dimension as shown in Fig. (3). The inner surface of the die was covered with heating resistance silicon grease in order to facilitate the recovery of the pattern from the die. Then the die was cooled either by leaving it overnight at room temperature or by using a chiller filled with water at. 4 °C for about 30 minutes. The materials that were used for the experimental work were; Paraffin wax, Carnauba wax, Dammar resin and pentaerythritol filler.

Quality Tests

Melting point

Melting point was measured using ASTM D127-63 (IP 133/79). Specimens were deposited on two thermometer bulbs by dipping chilled thermometers into hot melted samples. Then the thermometers carrying the specimens were placed in test tubes and heated by means of water bath till the specimens melt and the first drop of sample falls from each thermometer. The average temperature at which these drops fall is considered as the melting point of the sample. The accuracy of the measured temperature falls within ± 0.1 °C.

Congealing point

Congealing point was analyzed according to ASTM D938-71 (IP. 76/7-0). A sample of pattern material was melted and a drop was made to adhere to the bulb of a thermometer by using a 250 ml prewarmed flask as an air jacket, the droplet on the bulb was allowed to cool at a fixed rate until it congeals. The congealing point is observed as the temperature at which the droplet ceases to flow when the thermometer was turned. The accuracy of the measured temperature falls within in ± 0.1°C.

Penetration

Penetration was measured according to ASTM D5-73 (IP. 49/79). The penetration was determined at 25 °C using StanHop Seta pentrometer by means of which a standard needle was applied to the sample for five seconds under a load of 50 g.

Ash content

Ash content of pattern material was measured according to ASTM D482-80 (IP. 4/81). Ash content was measured by using a crucible. The empty crucible was preheated to about 800 °C. Then the container was left to coo I to room temperature and then it was weighed to the nearest 0.1 mg. About 110 g if pattern' material was weighed and then it was ignited in the container and allowed to bum until only ash and carbon remains. The carbonaceous residue is reduced to ash by heating in a furnace at 775 °C, cooled and weighed. This process is repeated for three times till a constant weight is obtained. The weight of ash was calculated as a percentage of the original sample, as follows:

$$\text{Ash percent} = \frac{W_1}{W_2} \times 100$$

where W_1 is the weight of ash (g), and W_2 is the sample weight (g).

Linear shrinkage

Linear shrinkage was measured at 25 °C after 72 h from pattern casting (9). The three different diameters of the die, which were shown in Fig. (4), were measured with a suitable vernier with an accuracy of ± 0.02 mm; The average value of the three measurements were evaluated and reported as Xo. Similarly the three different diameters of the produced pattern were measured and the average values of these three measurements (X) were also evaluated. Linear shrinkage was calculated using the following relationship:

$$\text{Linear shrinkage(\%)} = \frac{X_0 - X}{X_0} \times 100$$

Dynamic viscosity

Dynamic viscosity of produced pattern materials was measured by using a coaxial cylinder rotational viscometer called (Fann Viscometer Model 35A). The rotating viscometers are suitable for the determination of flow behavior of both Newtonian and non-Newtonian liquids such as adhesives, fats and resins at high temperatures. According to such types of viscometers, the test fluid is contained in the annular space or shear gap between the concentric cylinders. Rotation of the outer cylinder at known velocities was controlled by means of electrical motor with variable speeds(10,11). The viscometer spindle was immersed in about 230 g of the pattern material, which was melted in 400 ml beaker supplied with a digital thermometer. This beaker was jacketed with an electrical heating cup. When the temperature of the sample reached about 5 °C above the test temperature (105 °C), then the viscometer was switched on. The temperature of the sample began to lower and when it becomes 100 °C, the reading of the viscometer was determined for speed of 3, 6,100, 200, 300 and 600 rpm.

The viscosity of the pattern material at 100 °C was computed by plotting shear rate versus shear stress and the slopes of the plot will represent dynamic viscosity.

Compatibility

When the pattern material cooled at room temperature without any suspension, change in color and precipitation and with only one layer formation, then the mixture is called compatible (12). The compatible mixture should look as one homogeneous liquid phase when it is hot and homogeneous solid phase when it is cold. When this happens, the mixture of waxes and resins could be considered as compatible mixture.

The compatibility term is solely related to waxes-resins mixture only. Pentearythritol filler was incompatible with all studied mixture in all different particle sizes with different studied temperatures. Since when the particle sizes of filler was up to about 100 µm, the particles will be suspended and when the filler particle sizes were greater than 100µm, the filler particles would precipitate.

RESULTS AND DISCUSSION

By keeping the weights of Carnauba wax, Pentaerythritol filler and Dammar resin, constant and varying the weights of paraffin wax from 14.8 to 113.3 g. The behavior of each physical property with respect to paraffin wax content were evaluated. Similarly by keeping the weights of three components constant and only varying the weight of the fourth component such as Carnauba wax or Pentaerythritol or Dammar resin, the behavior of each physical property were estimated as shown in Table (1). From these experiments the behaviors were obtained and shown later on.

Melting and congealing points

The temperature of melting and congealing point remain unaffected during variations in filler (Pentaerythritol) content as shown in Fig. (4). Since the melting point of Pentaerythritol is 250 °C and the mixing temperature of Pentaerythritol filler with wax-resin mixture is 120 °C. Therefore the used filler is thermally stable at this mixing temperature (6), i.e. not melted, and it is uniformly distributed in the mixture as solid particles.

The temperatures of melting and congealing points decrease with increasing the paraffin wax content in the range from 8-24 % wt., after that the two temperatures increase with increasing paraffin wax content up to40%wtas shown in Fig. (5). The melting and congealing points increase with increases of Carnauba wax content, which indicate that this wax acts as a melting point booster as shown in Fig. (6).

The temperature of melting and congealing points decrease with the decrease of Dammar content provided that the content of Carnauba wax plus paraffin wax is not more than 56 % wt. and the ratio of paraffin wax to Carnauba wax content is less than 0.8:1. Other than these two conditions, the temperatures of melting and congealing points increase with decreasing the Dammar content as shown in Fig. (7)

The melting point of a mixture containing equal amount of paraffin wax (melting point of 65 °C) and Dammar resin (melting point of 110 °C) is about49 °C[1]. While melting point of another mixture containing equal weight percent of Carnauba wax (melting point of 83 °C} and Dammar resin is about 66 °C C13). On the hand, the melting of the mixture consisting of 50 % wt. paraffin wax (melting point of 54 °C) and 50 % wt. of Carnauba wax (melting point of 85.5 °C) is about 81.4 ""C (li;). Therefore the melting point of a ternary mixture of paraffin wax, Carnauba wax and Dammar resin will be effected by the melting points of the above three binary mixtures.

Linear shrinkage

Linear shrinkage of the obtained patterns increases with increasingparaffin wax content and/or Carnauba wax content, while it decreases with increasing filler content of Dammar resin content as shown in Figs. (8-11). Since linear shrinkage of all waxes is high (during solidification) due to their crystalline structure, therefore waxes increase linear shrinkage of the produced patterns. While Pentaerythritol fillers was essentially added to minimize linear shrinkage of the pattern material by forming a secondary bonds between waxes and resins. Dammar resin usually has an amorphous structure therefore it reduces the shrinkage of the pattern material.

Penetration (Hardness)

Penetration of the produced pattern materials decreases with increasing the Dammar resin content and/or Carnauba wax content and/or Pentaerythritolfrilol content Since vegetable waxes (such as Carnauba wax) has a hard surface, therefore they increase the hardness (i.e. decrease penetration). While therm op'lastic resin (such as Dammar) were also used to decrease the penetration. Also penetration increases with increasing the paraffin wax content since this wax has a high penetration value (low hardness), as shown in table (1).

Dynamic viscosity

The measurement of dynamic viscosity of the obtained samples at 100 °C shows that the viscosity of the mixture decreases with increasing the paraffin wax content. While the viscosity increases with increasing in Dammar content and/or Carnauba wax content and/or filler content as shown in Figs. (12-15). When plotting shear stress versus shear rate at constant temperature (100 °C) for four selected samples, a linear relationships were observed which indicates that the molten patterns are a New Ionian fluid.

Ash content

The ash content of the prepared pattern materials increases with the increase in Carnauba wax content. While it decreases with increasing either the paraffin wax or Dammar resin o r Pentaerythritol filler content, as shown in Figs. (16-19). The increase or decrease in ash content of the prepared samples is due to the' composition of mixture containing ash.

CONCLUSIONS

1. Paraffin wax, Carnaubawax, Dammar resin are compatible with each other when the mixing contains 8-40% wt. of paraffin wax, 8-40 % wt.,of Carnauba wax and 3-60 % wt. of Dam mar resin at 120 °C. Other weight percentage, even though, were compatible but they gave very poor quality.
2. Ash content, melting point, congealing point, linear shrinkage, viscosity and.hardness of the prepared pattern materials increase with the increasing in Carnaubawax content.
3. Viscosity, ash content and hardness decrease with increasing the paraffin wax content while linear shrinkage increase with increasing paraffin wax content.
4. Viscosity and hardness of the produced pattern materials increase with the increasing of Pentaerythritol filler.content while linear shrinkage and ash content decrease with increasing the Pentaerythritol filler content. The temperature of melting and congealing point remain unaffected during variations in filler (Pentaerythritol) content.
5. Viscosity .and hardness of the produced pattern materials increase with increasing of Dammar resin content while linear shrinkage and ash content decrease with increasing the Dammar resin content.

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Table (1) Physical properties of the produced pattern material

No	Composition					Tests						
	P.W.	C.W	P.F	D.R.	T. Wt.	M. Pt (°C)	Cong Pt. (°C)	ΔT (°C)	μ (P)	Pent dmm	L. Sh. (%)	Ash Cont. (wt. %)
1	14.8	80	50	40	184.8	65.7	62.3	3.4	33.28	2	0.84	0.0344
2	32.4	80	50	40	202.4	64.4	60.1	4.3	11.35	2	0.93	0.0291
3	53.7	80	50	40	223.7	63.9	59.3	4.6	5.78	3	0.99	0.0263
4	80	80	50	40	250	67.5	62.4	5.1	4.12	4	1.02	0.0243
5	113.3	80	50	40	283.3	68.5	62.2	5.6	1.83	5	1.12	0.0208
6	80	14.8	50	40	184.8	62.9	57.8	5.1	1.46	5	0.81	0.0089
7	80	32.4	50	40	202.4	65.7	60.4	5.3	2.01	5	0.90	0.0136
8	80	53.7	50	40	223.7	66.4	61.1	5.3	3.08	4	0.96	0.0210
9	80	80	50	40	250	67.5	62.3	5.2	4.12	4	1.02	0.0243
10	80	113.3	50	40	283.3	68.2	63.0	5.2	4.62	4	1.14	0.0300
11	80	80	10.5	40	210.5	67.7	62.4	5.3	1.96	5	1.38	0.0278
12	80	80	22.2	40	222.2	67.8	62.3	5.5	2.85	5	1.25	0.0267
13	80	80	35.3	40	235.3	67.6	62.1	5.5	3.71	5	1.18	0.0240
14	80	80	50	40	250	67.8	62.3	5.2	4.12	4	1.02	0.0243
15	80	80	66.7	40	266.7	67.9	62.6	5.3	4.44	4	0.88	0.0227
16	80	80	50	94.3	304.3	65.3	61.1	4.2	5.47	3	0.90	0.0203
17	80	80	50	73.8	283.8	64.6	60.0	4.6	4.86	4	0.94	0.0215
18	80	80	50	55.8	265.8	66.4	61.4	5.0	4.51	4	0.99	0.0231
19	80	80	50	40	250	67.5	62.3	5.2	4.12	4	1.02	0.0243
20	80	80	50	26	236	68.4	62.8	5.6	3.62	5	1.06	0.0266

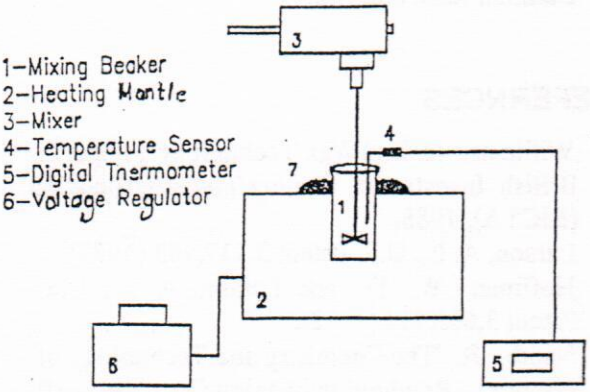

Fig. (1) Diagram of experimental equipment for preparing pattern material

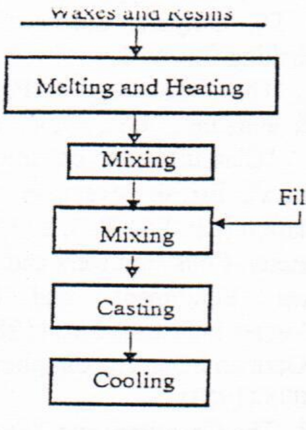

Fig. (2) Schematic diagram of the preparation of pattern material

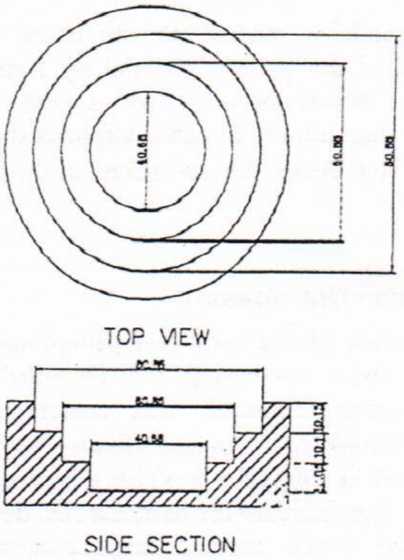

Fig. (3) Dimensions of the aluminum die

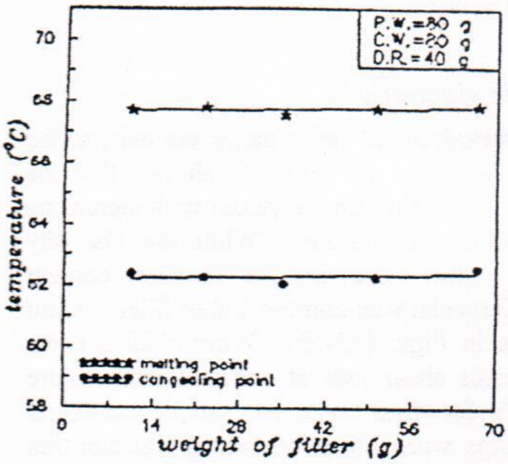

Fig. (4) Effect of the filter height on melting and congealing point temperatures

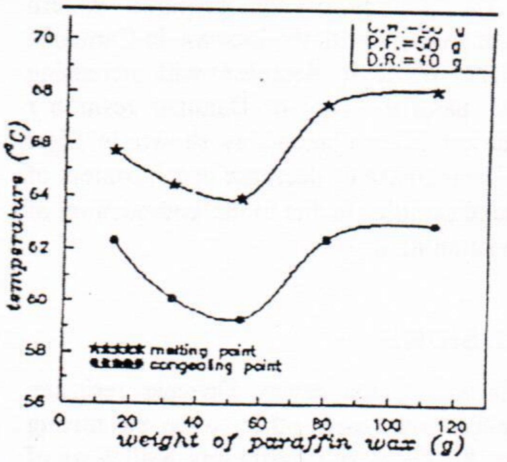

Fig. (5) Effect of paraffin wax weight on melting and congealing point temperatures

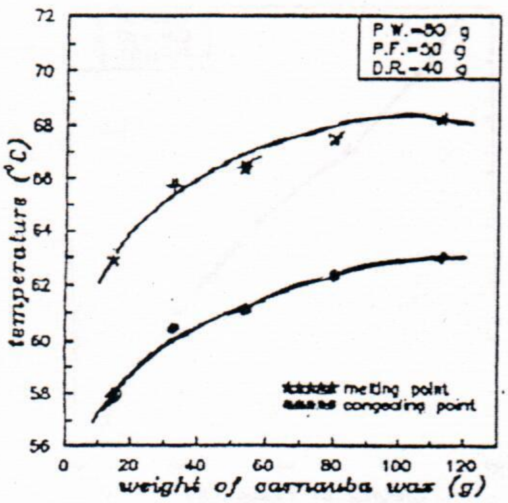

Fig. (6) Effect of Carnauba wax weight on melting and congealing point temperatures

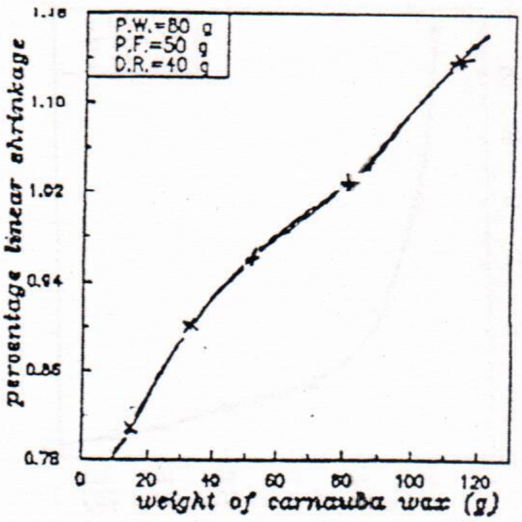

Fig.(9) Effect of Carnauba wax weight on linear shrinkage

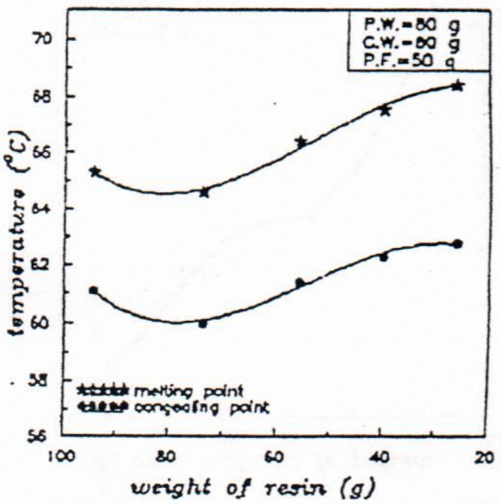

Fig. (7) Effect of Dammar resin weight on melting and congealing point temperatures

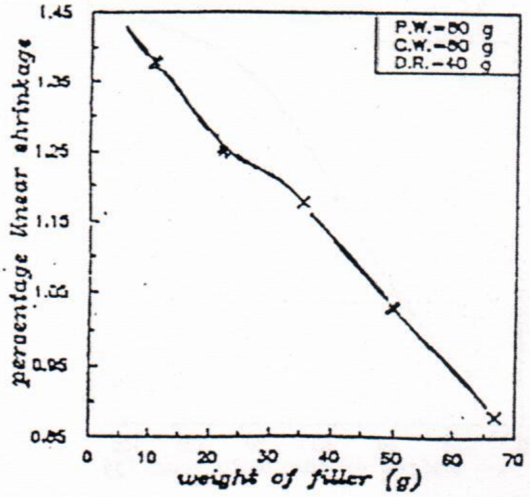

Fig.(10) Effect of the filter weight on linear shrinkage

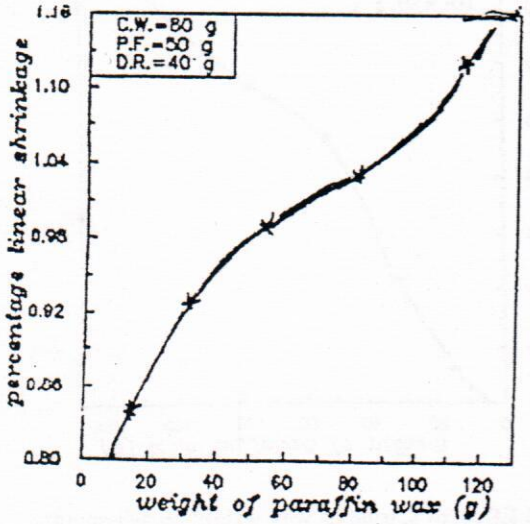

Fig.(8) Effect of paraffin wax weight on linear shrinkage

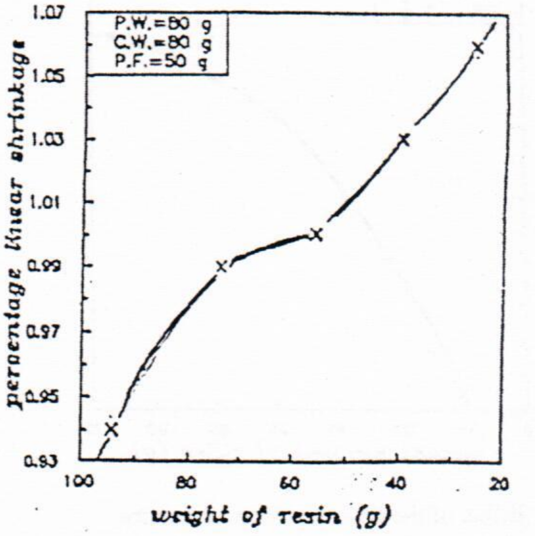

Fig.(11) Effect of Dammar resin weight on linear shrinkage

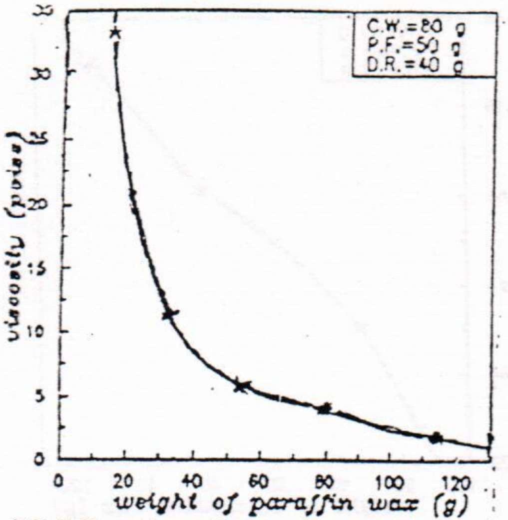

Fig. (12) Effect of paraffin wax weight on viscosity

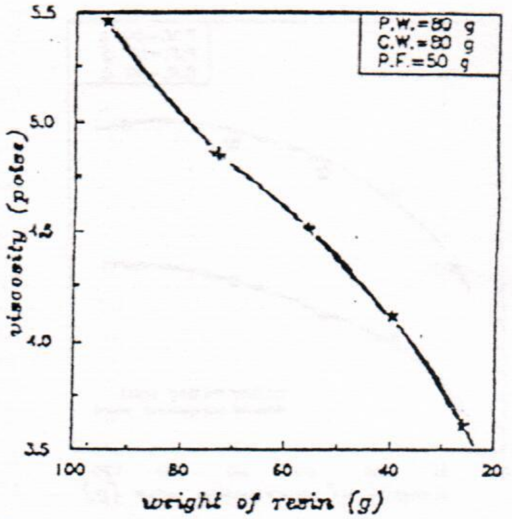

Fig. (15) Effect of Dammar resin weight on viscosity

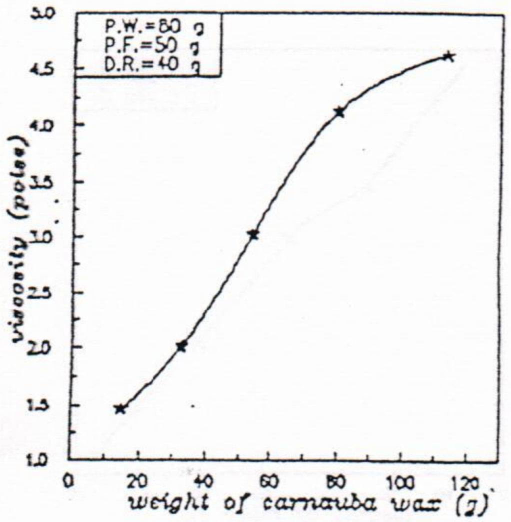

Fig.(13) Effect of Carnauba wax weight onviscosity

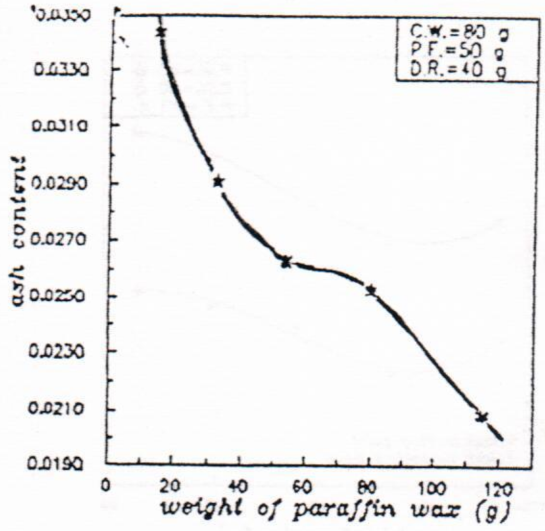

Fig. (16) Effect of paraffin wax weight on ash content

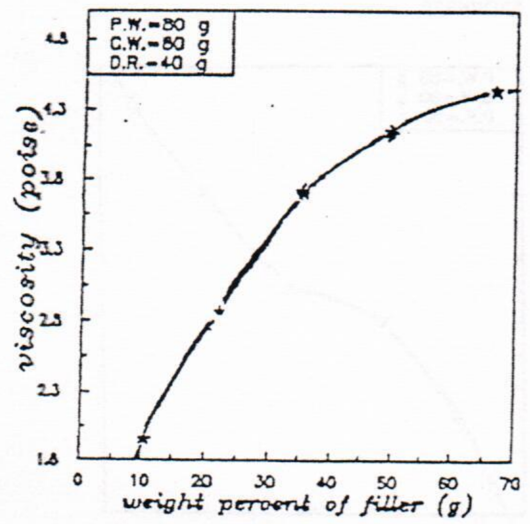

Fig. (14) Effect of the filter weight on viscosity

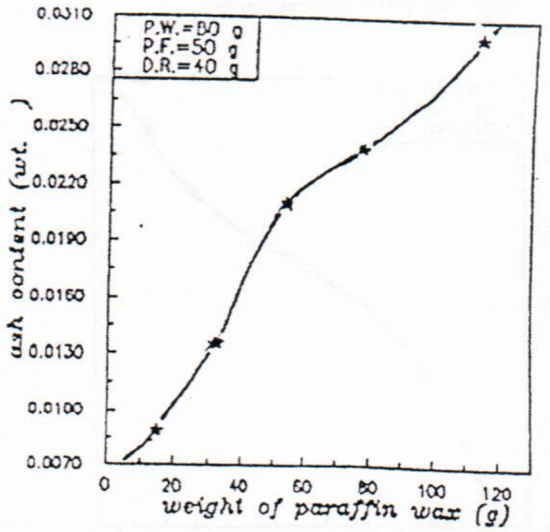

Fig. (17) Effect of Carnauba wax weight on ash content

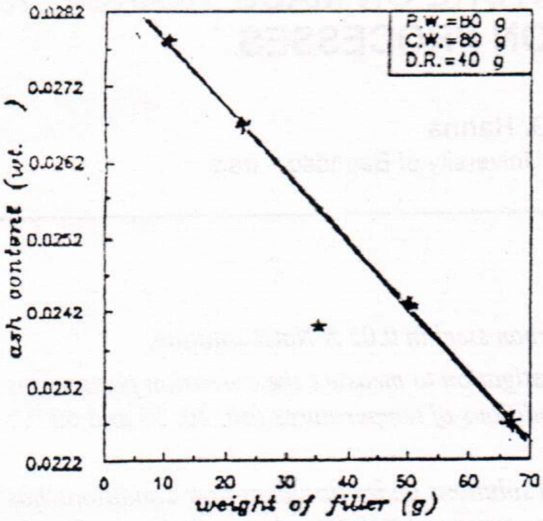

Fig. (18) Effect of the filter weight on ash content

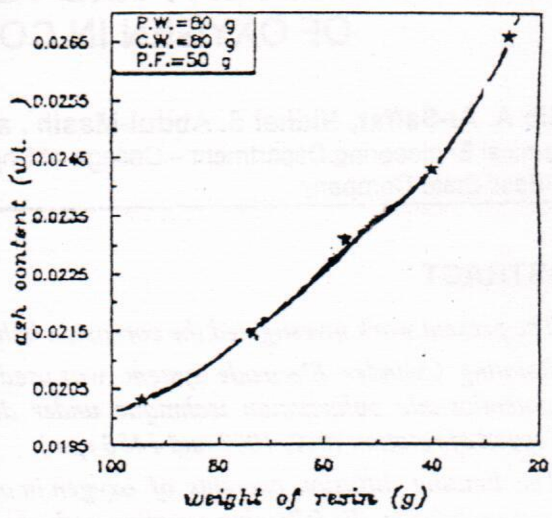

Fig. (19) Effect of Dammar resin weight on ash content