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# Effect of temperature on viscosity of modified unsaturated polyester resins

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## Abstract
Unsaturated polyester, UP, resins were obtained by reacting the propylene or ethylene glycol, PG or EG, maleic anhydride as a source of double bond, phthalic anhydride and isophthalic acid as dibasic acids. The condensate obtained was mixed with styrene monomer to get an unsaturated polyester resin formulation. The dilute UP resin solution thus obtained has a viscosity in the range 200–2000 cps. This viscosity changes sharply with temperature and affects resin processability. In this work three modified resin produced and their viscosity change in near ambient temperature studied. Results show that 30 degree increase in resin temperature decrease resin viscosity to one third**.**

**Keywords: unsaturated polyester resin, viscosity, temperature, modified resin, composite.**

## Introduction
Liquid composite molding (LCM) processes are routinely considered as a viable option to manufacture composite parts In this process, a fibrous perform is placed in a mold [1]. The mold is sealed and a liquid thermoset resin is injected to saturate the perform and cover all the fibers with resin. After the filling is complete, the thermoset resin is cured. In all cases, the flow of the resin through the perform is very important and resin viscosity must be low enough to facilate process. Unsaturated polyester resins (UP resins) are frequently used as polymer matrices in glass-fibre reinforced composites. UP resins used widely in LCM processes because of their excellent properties and low cost. But UP resins are temperature dependant and their viscosity changes sharply with temperature and their viscosity increases with temperature drop that results process problems LCM processes[2].The present work concerns this phenomena and tries to understand and control temperature dependency of UP resin.

**Viscosity measurement**
Viscosity measurement made by Brookfield viscometer dvII and spindle 2 and 100 rpm rate.

## Experimntal
**Material**
Maleic anhydride, isophthalic acid, ethylene glycol, propylene glycol, styrene benzoic acid were industrial grade without further purification. The methanol, potassium hydroxide, and phenolphthalein indicator used were reagent grade.

**Resin preparation**
Reactions were carried out in a four necked flat bottom flask (250 ml) fitted with a condenser, mechanical stirrer operated at approximately 100 rpm and a nitrogen gas inlet to facilitate the removal of water and oxygen from system.The progress of the reaction was determined by taking small (relative to the reaction mass) and accurately weighed samples (approximately 0.2 g) at appropriate time intervals and measuring the carboxyl group content. Each sample was dissolved in approximately 50 ml of a aceton and titrated with 0.1N methanolic potassium hydroxide using phenolphthalein as indicator [3].
*Main UP resin:* Isophthalic acid (0.5 mole) and (1.1 mole) mixture of glycols charged in to flask .
The mixture was heated for 1 h at 160 °C, then the temperature of the reaction mixture was gradually raised (10 °C/h) until it reached 210 °C. Then mixture cooled down to80 °C Maleic anhydride (0.5 mole) and hydroquinone (about 20 mg)as retardant added to mixture then the temperature of the reaction mixture was gradually raised to 210 °C . reaction proceed to acid value about 30mgKOH/g resin. Mixture temperature cooled to 140°C and styrene was added to mixture to obtain 65% resin and cooled immediately to room temperature.

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*Modified UP resin (A):* After acid value of main resin decreased to about 30mgKOH/g resin ,ethylene glycol (0.35 mole) was added to flax mixture and temperature fixed at 194°C until acid value of mixture decreased to about 10mgKOH/g resin. Then temperatures raised to 210 °C and excess glycols distilled from mixture. Mixture temperature cooled to 140°C and styrene was added to mixture to obtain 65% resin and cooled immediately to room temperatures.

*Modified UP resin (B):* After acid value of main resin decreased to about 30mgKOH/g resin, ethylene glycol (0.35 mole) was added to flax mixture and temperature fixed at 194°C until acid value about 10mgKOH/g resin. Then temperature raised to 210 °C and excess glycols distilled from mixture. Then (0.15 mole) benzoic acid was added to flax mixture and temperature raised to 220°C until acid value of mixture decreased to about 10mgKOH/g resin. Finally mixture temperature cooled to 140°C and styrene was added to mixture to obtain 65% resin and cooled immediately to room temperature.

## Results and Discussion

Viscosity of produced resins measured by Brookfield viscometer in near ambient temperature and results are presented in Fig. 1.results shows that viscosity of main resin decrease sharply with temperature increase. These phenomena occurred in systems with hydrogen bonding. In UP systems hydrogen bonding take place because high amount of carboxyl, hydroxyl and acid groups are exists in mixture. Acid groups produce highly hydrogen bonding systems and neutralizing them could decrease hydrogen bonding of system and its temperature dependency.

In resin A and B neutralizing acid groups from 30 to 10 decreases resin viscosity and viscosity change with temperature is smoother as shown in fig.1.

Fig.2. presents viscosity of modified resins and their variation with temperature. Both resins show temperature dependency and their viscosity decrease with temperature that explain hydrogen bonding exist in system because acid number of resin is about 10 in both and acid groups show their effect on viscosity.

To emphasize effect of hydroxyl groups in resin viscosity one can compare resin A and B as showed in fig.2. Resin B has shorter content of hydroxyl groups than resin A because of capping treatment made by benzoic acid on it .As it is obvious in fig.2 this treatment has not significant effect on resin viscosity and its temperature dependency .Therefore hydroxyl groups have minor effect on viscosity .

## Conclusion

Viscosity of UP resin is dependent on their hydrogen bonding and acid groups have major effect on it. Modifying this resin could reduce their viscosity and their temperature dependency.

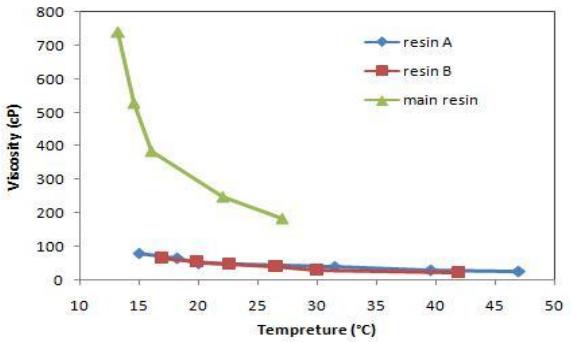


**Fig 1. viscosity of resins versus temperature**

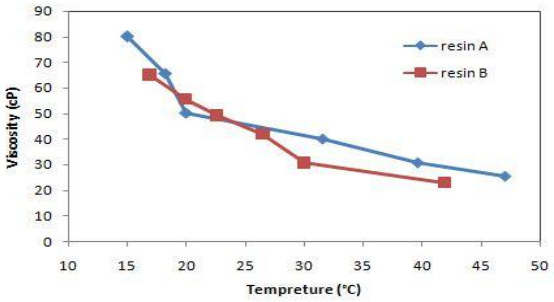


**Fig 2. Viscosity of modified resins versus temperature**

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