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Synthesis and Evaluation of Lap Shear Strength of Polyurethane Hot Melt Adhesive

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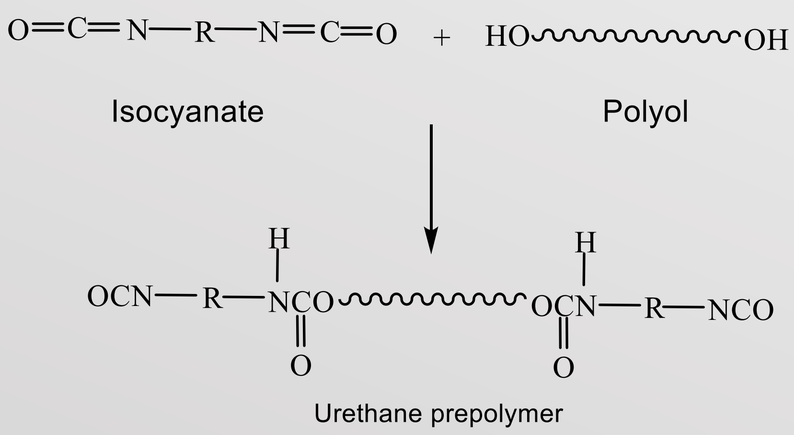
Abstract
Polyurethane hot melt adhesives (HMPUA) are extensively utilized for their notable benefits. A lap shear test was used to check the strength of the synthesized adhesive. The highest lap shear strength of the HMPUA adhesive reached up to 4.17 MPa after 10 days of curing.

Keywords: polyurethane; hot-melt adhesive; lap shear strengt.

Introduction
Polyurethane (PU) is a type of polymer that features carbamate bonds (NH-COO) in its main chain, which can be obtained through a stepwise addition process involving isocyanates and polyols [1]. Preparation of urethane occurs from the reaction between the polyol hydroxyl group with isocyanate group using a suitable catalyst (scheme 1). Sometimes, to minimize the free -NCO groups in the formed polyurethane, the NCO/OH index is set to its lowest value, or other hydroxyl groups are also used. HMPUA without any free isocyanate groups can be completely cured at room temperature, which leads to a long shelf life in an open environment, which is more suitable for practical use [2,3]. The polymer widely used in various industries, polyurethane has a long service life, high resistance to impact loading, and low wear loss. Some common uses of polyurethanes include packaging, coatings, automobiles, furniture, construction, and adhesives [4]. Polyurethane has gained increasing attention in recent years due to environmental concerns. Traditional solvent-based polyurethane adhesives are being gradually replaced by environmentally friendly alternatives, as they release toxic volatile organic compounds (VOCs) during usage. As a result, eco-friendly adhesives are becoming a key area of development in the adhesive industries. HMPUA are particularly favored for their solvent-free simple sizing, easy storage, and transportation properties [5].



scheme.1: Reaction of polyol hydroxyl group with isocyanate [2].

Experimental
A 250 mL round-bottom flask with four necks, a mechanical stirrer, and a thermometer were used to make the HMPUA. Polypropylene Glycol (Mn= 1000 g/mol, 70 w%), 1,4-butanediol (3.10 w%), and glycerin (2.00 w%) were mixed and dried under reduced pressure (120 °C for 2-3 h). The temperature was cooled down to 60-70 °C, and the reaction was carried out with addition of toluene diisocyanate (24.50 w%) with a constant NCO/OH ratio of 1/05 along with 0.5 w% dimorpholinodiethyl ether (DMDEE) catalyst was added to the flask and stirred (2-3 hours at a temperature of 70-80 °C). The mixture was poured into a teflon mold and the formed film reacted at 50 °C for 18-24 h in an oven.

Results & Discussion
structure of the curred sample of the polyurethane was monitored using ATR-FTIR spectroscopy (Figure 1). The appearance of a sharp peak around 1728 cm^{-1} region related to the carbonyl group of the disappearance of the NCO group peak in the around 2270 cm^{-1} region and the appearance of a weak N-H peak in the around 3290 cm^{-1} region indicate the formation of polyurethane hot melt adhesive. The adhesion properties were studied using lap shear strength test on the substrate/HMPUA/substrate joint. The HMPUA film was cut into rectangle shapes (25 mm × 12.5 mm) and then placed between two identical substrates (100 mm × 25 mm × 2 mm) with an overlap area (25 mm × 12.5 mm). A plate of stainless steel was used as a typical adhesion substrate, and the substrates with adhesive film were held together by paper clips. The HMPUA samples were melted at 130 °C and evenly coated on one piece to form a film with a size of (25 mm × 10 mm × 0.1 mm). The bonded substrates were kept at a room temperature of (23±2 °C) and a relative humidity of 45%-50% RH at different times to cure. According to Figure 2, which examines the curing of adhesive in different periods of time, it is clear that the complete curing of adhesive is done after 10 days. The final strength of bonding value reaches to 4.17 MPa.

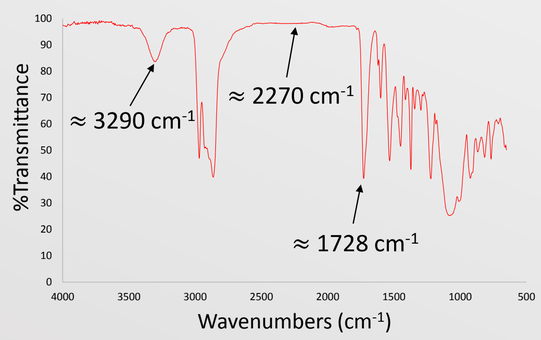


Fig. 1: ATR-FTIR analysis of the HMPUA.

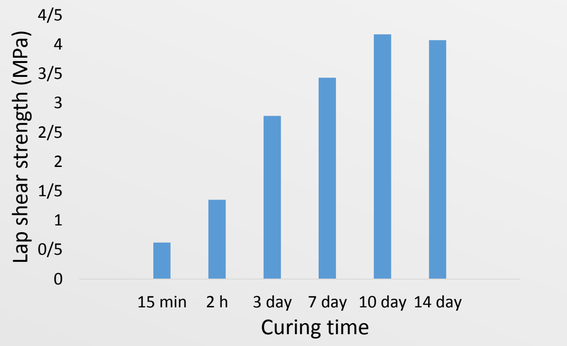


Fig. 2: Lap shear strength of HMPUA to plate of stainless steel under different curing times at room temperature.

Conclusion
A polyurethane hot melt adhesive was prepared and analysed using ATR-FTIR technical, we see the formation of urethane groups and the structure of the synthesized adhesive. The synthesized adhesive is completely cured after 10 days and its lap shear strength is 4.17 MPa.

Acknowledgements
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