

Polypropylene

Welding

Doeflex Industries Limited: PP (process type: thermoforming; product form: sheet)

Polypropylene is a non-polar, chemically inert material and cannot be welded using the high frequency equipment that is commonly used for flexible PVC. However, thermal bonding techniques work well. In some fields, polypropylene moldings and thick sheets are welded by using hot gas, hot plate or friction techniques. These methods have not been found useful for Doeflex polypropylene binders.

Reference: *Thermoforming with Polypropylene and Polyethylene*, supplier data sheets - Doeflex Industries Limited.

Hoechst AG: Hostacom (reinforcement: glass fiber)

Hot gas welding, heated tool welding, friction welding and vibration welding are all suitable methods for welding Hostacom. Ultrasonic welding is possible only under "near field" conditions.

Hostacom moldings are only conditionally suitable for weld designs in the context of semi-finished product processing (chemical apparatus engineering).

Reference: *Hostacom Reinforced Polypropylene*, supplier design guide (B115BRE9072/046) - Hoechst AG, 1992.

Hoechst AG: Hostalen

Good weldability is a special advantage when laying pressurized pipes. All Hostalen PP pressurized pipe materials can be combined homogeneously and permanently with each other, both through heating tool socket fusion welding and also with heated tool butt welding or extrusion welding. A variety of weld fittings is available for laying pipes simply. This includes fittings for connecting plastic to metal such as socket welds with metal thread inserts or clamp screw couplings.

Reference: *Future - The Hoechst Magazine*, supplier newsletter (HB920EBR/014) - Hoechst, 1992.

Heated Tool Welding

Doeflex Industries Limited: PP (process type: thermoforming; product form: sheet)

It is sometimes required that a clear window be attached to a polypropylene binder, and the ideal fixing method is heated tool welding.

Polypropylene film with a thickness of between 150 and 250 microns is generally used, together with a heated brass tool supported in a simple press. Temperatures, times and pressures should be adjusted to give a good seal without causing excessive flow. Heated tool welding is very slow for a sheet above 0.5 mm.

For fixing a small window, hand pressure, temperatures of 150°C - 180°C and times of 2 - 5 seconds have been found satisfactory.

Reference: *Thermoforming with Polypropylene and Polyethylene*, supplier data sheets - Doeflex Industries Limited.

Solvay: Fortilene

Heated tool welding can assure a virtually 100% air, water, or dust seal and has found great acceptance in the welding of polypropylene battery cases. Large parts such as refrigerator or washing machine doors, small parts, and parts with irregular shapes or thick walls can all be welded by fusion welding. One added benefit is that two different materials such as polypropylene and polyethylene can often be joined by this method.

Reference: *Fortilene Polypropylene Properties, Processing, and Design Manual*, supplier design guide - Soltex, 1981.

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The effect of welding parameters on non-contact hot plate butt welding of polypropylene was investigated. For a given hot plate temperature, an optimum heating time and forging pressure was found. Increasing or decreasing the heating time and/or pressure from the optimum value resulted in lower joint strength. Increasing the forging time improved the joint strength. A "push and pull" technique was applied during the forging stage to reduce adverse molecular orientation. This consisted of applying a push force of around 200 N for 1 second followed by a "pull" stage which consists of reducing the welding force to zero.

Reference: Lin, T.T., Staicovici, S., Benatar, A., *Non-Contact Hot Plate Welding of Polypropylene*, ANTEC 1996, conference proceedings - Society of Plastics Engineers, 1996.

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In heated tool welding of polypropylene, tensile strengths approaching that of the parent material can be achieved with displacements of about 2 mm. An important aspect was the heat soak time, which was influential in obtaining high joint strengths. Ideally, the stops should be as close to the joint interface as possible, consistent with bringing the joint interface into intimate contact with the heating element. After displacement stops were reached, the heating time controlled the amount of heat soak. The optimum range found for heating time was 10-20 sec. Without the application of displacement limit stops the heat soaked material was squeezed out during the heating stage thus giving joints of low strength.

The hot plate temperature was found to be a less critical parameter than either heating pressure or time. Although the material displacement increased substantially with increasing temperature, the joint strength remained around 30 N/mm² for platen temperatures between 215-260°C.

Two process parameters were involved in the weld consolidation stage: consolidation pressure and time. The pressure affected the material displacement, with the major portion occurring within 2 sec of application. The consolidation time showed no discernible trends on either material displacement or tensile strength beyond 5 sec.

Reference: Watson, M., Murch, M., *Recent Developments in Hot Plate Welding of Thermoplastics*, ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

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This study focused on the effects of heating temperatures and heating times on the microstructure and properties of the hot plate weld. Polypropylene was used due to its large crystal structure which can be observed easily under a microscope. The goal was to find the correlation between microstructure and weld quality in hot plate welding.

The characterization of the heat affected zone (HAZ) around welds plays a prominent role in determining the weld quality of the thermoplastic welding. The influence of HAZ microstructure on the weld strength was investigated by comparing micrographs of microtomed samples and their tensile strength. The weld joints which had less inhomogeneity along the joining interface had better weld quality. High heating temperatures might be applied to reduce the welding cycle time. However, the heating time should be carefully selected in such cases, since the weld quality was very sensitive to the variation of heating time.

Reference: Nieh, J.Y., Lee, L.J., *Morphological Characterization of the Heat-Affected Zone (HAZ) in Hot Plate Welding*, ANTEC 1993, conference proceedings - Society of Plastics Engineers, 1993.

PP

The effect of hot plate welding parameters on the butt weld strength of polypropylene plates was investigated. Increasing the heating time increased the weld strength and the heating displacement.. Increasing the heating pressure decreased the weld strength. Increasing the change-over time decreased both the weld strength and welding displacement. Increasing the hold time increased weld strength, and increasing the welding pressure decreased the weld strength.

Reference: Lin, T.T., Benatar, A., *Effects of Hot Plate Welding Parameters on the Weld Strength of Polypropylene*, ANTEC 1993, conference proceedings - Society of Plastics Engineers, 1993.

Vibration Welding

BASF AG: Novolen 1100L

On reaching the steady state phase in the vibration welding process, the mechanical behavior of the weld correlates with three typical structural build-ups. High pressure (3.0 MPa) generates a weld with different appearances in the center and at the edge of the bars. The thickness in the center is about 0.08 mm, at the edge the weld opens to a delta of about 0.9 mm. Enlargements show that the joining plane itself is characterized by an optically bright line. This line is attached to a layer whose microstructure could not be defined by microscopy. The transition from this layer to the bulk material is formed by a thin layer of deformed spherulites. For these welds tensile strength was observed at a welding pressure of 2.0 MPa. Microtomed slices showed that the weld is about 0.07 mm thick and delta areas (in which the weld opens) are not present. These welds show the following microstructural zones, the joining plane, the inner layer without microstructure and the transition layer to the bulk material formed by deformed spherulites. Welds produced with low joining pressure (0.5 MPa) show three microstructural zones: first the inner layer, second, a so-called recrystallized zone with spherulites of different size. The third zone is the transition layer of deformed spherulites. In contrast to the two other types, the thickness of the entire weld is about three times as large. For these welds the tensile strength was high.

Reference: Giese, M., Ehrenstein, G.W., *Studies of the Deformation and Failure Behavior of Vibration Welded Polypropylene Welds*, ANTEC 1992, conference proceedings - Society of Plastics Engineers, 1992.

BASF AG: Novolen 1100L

The results of this vibration welding study show that high amplitude and high welding pressure lead to a short welding time. However, in spite of reaching phase 3 in the welding cycle (phase in which a steady state melt is achieved and the penetration increases linearly with time until vibration stops), the impact strength of the weld is low. The mechanical behavior of the welds can be determined through analysis of the microstructure. Welds with only two layers (inner layer and band of deformed spherulites) with and without delta shaped areas have unsatisfactory impact strength. Only the welds with three different microstructural layers and a large weld thickness lead to high impact resistance. These welds occur if vibration stops in phase three with low pressure independent of amplitude.

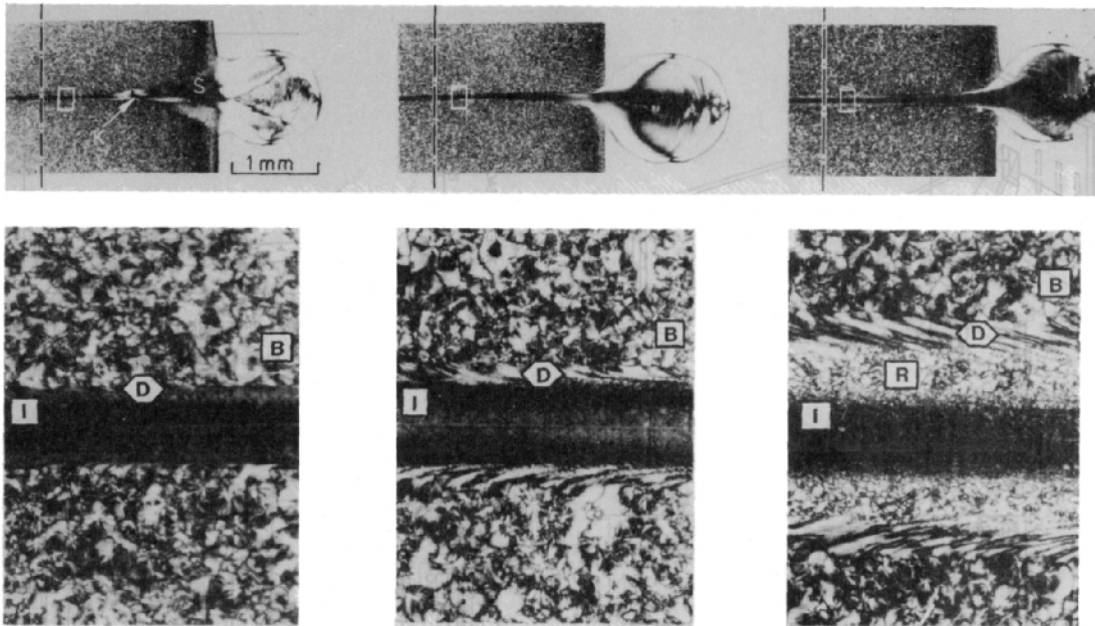


Figure 56.1: Polarization micrographs showing microstructures of three typical vibration welds of a polypropylene homopolymer. Welding pressures are a) 8.0 MPa (1160 psi) b) 2.0 MPa (290 psi) c) 0.5 MPa (72 psi). Weld amplitude is 0.7 mm (0.03 in.). In the upper micrographs, high pressure results in an area of weld thickness of about 50 μm (0.002 in.) gradually increasing in thickness to 1 mm (0.04 in.); high pressure causes the melt flow to change from laminar in the boxed area to turbulent at point K. At lower pressures, this area of greater weld thickness is not present. In the lower micrographs, higher pressure welds (8.0 MPa, 2.0 MPa) are separated from the bulk material (B) by two zones: an inner layer (I) adjacent to the joining plane and a layer of deformed spherulites (D). Low pressure welds (0.5 MPa) are composed of three zones: an inner layer (I), a middle zone with spherulites of different sizes (R), and a third layer of deformed spherulites (D).

Reference: Schlarb, A.K., Ehrenstein, G.W., *The Impact Strength of Butt Welded Vibration Welds Related to Microstructure and Welding History*, ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

Solvay: Fortilene

In vibration welding, parts with complex or irregular shapes, and very large (up to 20 in. (508 mm)) parts can be welded. In addition, the parts can be oriented. This is important when welding, for example, a part with mounting brackets or inlet-outlet connections. Another important advantage is that parts made from dissimilar materials can often be joined. Plastics with melting point differences as great as 100°F (38°C) have been successfully welded using this technique. Applications that have been evaluated for vibration welding include fuel pumps, motorcycle fuel tanks, solenoid valves, and automotive emission control canisters.

Reference: *Fortilene Polypropylene Properties, Processing, and Design Manual*, supplier design guide - Soltex, 1981.

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A large American electrical appliance company converted its production line of glass-filled polypropylene dishwasher pump housings from hot-plate to vibration welding. The change made the operation faster, easier, more energy efficient and easier to maintain. Control of strength and appearance were also better.

The process is less labor intensive than hot-plate welding. With hot-plate welding two welders were needed for three shifts and a third half the time. Leak testing had to be carried out at a separate station after allowing time for parts to cool. In addition, venting systems were needed to eliminate gases generated by the process.

These problems were eliminated by vibration welding. One vibration welder replaced the two hot-plate welders. A leak tester attached to the frame of the vibration welder enables the operator to test a part immediately after its assembly and while the next part is being welded. Cooling time is not required because vibration welding does not heat the part. Although pump-housing halves warped from moulding, warping in the final product was minimized because the components are clamped under pressure before welding. Cycle time, 30 seconds for the hot-plate welder, was reduced to 10 seconds for the vibration welder including testing.

Design of the pump housing remained unchanged despite the shift from hot-plate welding to vibration welding.

In a study on energy consumption, the manufacturer found that the vibration welder required only 2622 kilowatt-hours of electricity per year, compared with 38,000 kilowatt-hours for the hot-plate welder which draws power constantly to maintain temperature even when it is not welding. Vibration welding required power only during the weld cycle.

Reference: White, P., *Vibration Welding*, Making It With Plastics, trade journal 1987.

Spin Welding

Solvay: Fortilene

The main requirement for parts to be spin welded is that they, or the joint area, must be round if the part is noncircular. Also, the contacting area must be in a single plane or at least in concentric planes. Machinery varies from small, hand-operated, often homemade units, to custom-made automated units integrated into an automatic assembly line. Small portion packages for juices and yogurt are produced by this method.

Reference: *Fortilene Polypropylene Properties, Processing, and Design Manual*, supplier design guide - Soltex, 1981.

Ultrasonic Welding

Doeflex Industries Limited: PP (process type: thermoforming; product form: sheet)

Ultrasonic welding should be used for a sheet above 0.5 mm thickness.

Polypropylene does not weld as easily as rigid, hard polymers, such as polystyrene, but good results can be achieved if a high amplitude, high energy source is used. However, only close welding is possible since polypropylene does not transmit ultrasonic waves well enough to allow distant welding.

Reference: *Thermoforming with Polypropylene and Polyethylene*, supplier data sheets - Doeflex Industries Limited.

PP (features: 5.8 mm thick)

Most olefin fibers, woven and non-woven, have good ultrasonic welding characteristics.

Reference: *Ultrasonic Sealing and Slitting of Synthetic Fabrics*, supplier technical report - Sonic & Materials, Inc.

PP

In order to achieve maximum ultrasonic weld joint strengths in polypropylene, processors should consider the following:

- Welding input parameters optimization needs to be linked directly to part acceptance criteria, whether it be pull or burst strength, hermetic seal integrity, or other factors.
- Reliance on travel distance, weld energy, or time should not be made in order to assume maximum joint strength while trying to optimize the process.
- Maximum joint strengths can be obtained by welding at a primary weld force and then switching to a lower weld force.
- Changing amplitude during the welding cycle either upwards or downward does not have a positive impact on weld strength.
- Precise, closed-loop control over the weld force is critical to weld strength, since minor force changes greatly influence weld strength.

Furthermore, in order to achieve maximum joint strengths in polypropylene, designers need to both incorporate a proper joint design and use a secondary lower weld force.

Reference: Nayar, S.K., Cavaleri, M.E., Brostrom, M., *Morphological Changes in Ultrasonically Welded Polypropylene*, ANTEC 1993, conference proceedings - Society of Plastics Engineers, 1993.

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Near field ultrasonic welding of polypropylene was successful, but amorphous materials (ABS, impact polystyrene) produced stronger bonds. It was generally found that increasing the weld pressure initially increases the weld strength, with further increase in pressure decreasing strength due to unfavorable molecular alignment. Increasing the weld time increased energy dissipated and strength; the strength levelled off at weld times greater than 1.5 seconds. Increasing the amplitude of vibration increased the energy dissipated and strength more than with amorphous polymers such as ABS and polystyrene - with the exception of low amplitudes.

Reference: Benatar, A., Eswaran, R.V., *Near-Field Ultrasonic Welding of Thermoplastics*, ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

PP

Far field ultrasonic welding of polypropylene was not successful. The parts melted at the horn/ part interface with little or no melting of the energy director. It is suggested that for semicrystalline polymers, the length of the part should be chosen such that the joint interface is at a displacement antinode. This is done by designing the top part to be a half a wavelength. This will make far field ultrasonic welding as effective for semicrystalline polymers as it is for amorphous polymers.

Reference: Benatar, A., Cheng, Z., *Far-Field Ultrasonic Welding of Thermoplastics*, ANTEC 1989, conference proceedings - Society of Plastics Engineers, 1989.

PP (product form: non woven filter)

In this application, the welding of non woven polypropylene filters, the periphery of a filter was ultrasonically welded to block out contaminants. The problem was consistency because of inconsistent density in the non woven fabric. This density variation is magnified when the part is welded, due to the sharp transition of the material as it melts. The power draw remains fairly constant for most of the process yet rises dramatically at the end of the weld when the material melts. If the weld time extends beyond this point, over welding occurs. If the weld is discontinued prior to this point, no fusion occurs. Thus, a proper weld time has a very narrow range.

When the amplitude was reduced at a pre-set power level, the slope of the power curve was reduced. This resulted in slowing the process and controlling the melt of the material which created a more robust process and consistent/ uniform welds.

Reference: Grewell, D.A., Frantz, J.L., *Amplitude Control in Ultrasonic Welding of Thermoplastics*, ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

Electromagnetic Welding

Solvay: Fortilene

Electromagnetic welding lends itself well to automation and produces structural, hermetic or high pressure welds. The process works well for polypropylene and offers several advantages:

1. The size of the bond can vary from a small spot to a long, continuous weld.
2. Irregular bond surfaces due to mold or heat shrinkage, for example, do not affect the weld.
3. The bond area need not be symmetrical.

Reference: *Fortilene Polypropylene Properties, Processing, and Design Manual*, supplier design guide - Soltex, 1981.

PP (material composition: 40% glass mat)

A GMT 40% glass mat composite with a polypropylene matrix is used to produce structural load floors for station wagons. Initially the GMT material replaced stamped steel which offered decreases in weight and less noise under vibration testing than the steel load floors. The load floor had to withstand a static load of 2.107 kg/m² at 82.2°C without deflecting more than one inch. The finished component also had to withstand a 15° torque test without bond failure. In order to meet these requirements, continuous welding of the two halves was necessary.

The use of EMA compound at the interface of the flat panel and the ribbed shell was critical in attaining the necessary structural weld. Since polypropylene is added to the weld interface the difficulties associated with the high glass content of the GMT were overcome. The EMA material actually bonds to the glass and welds to the surrounding polypropylene matrix. As the EMA material melts and flows under pressure, the surface irregularities are filled. The resultant weld provides a uniform structural weld between the two mating parts.

Polypropylene is perhaps one of the most difficult thermoplastic materials to reliably bond together. Polypropylene is perhaps the easiest thermoplastic material for the EMA process to weld together. The EMA process is currently used for a number of polypropylene applications. One specific application welds a two piece polypropylene tea kettle unit together. The EMA process was selected for this particular application for a number of reasons. Aesthetics played a key role in the decision to use the EMA process. The EMA process provides better aesthetics and part fit than the hot plate approach. This is achieved through the standard practice of using a completely contained joint. The fixturing utilized with the EMA process provides exact part alignment 100% of the time. Obviously, reliability is critical to this type of application. The EMA process provides for near 100% repeatability and near 100% leak proof reliability. The EMA process also provides for a fast cycle time, in this case 11 seconds

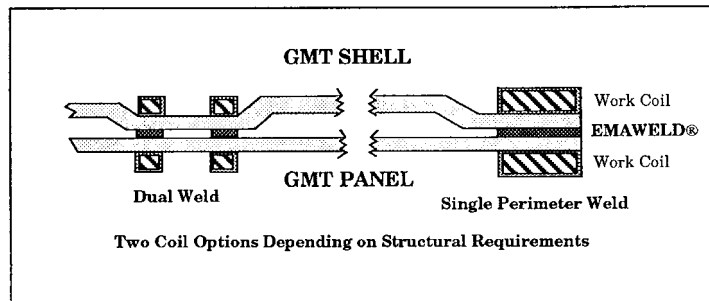


Figure 56.2: GMT 40% glass mat composite with a polypropylene matrix structural load floor for station wagons.

Reference: Chookazian, S. M., *Electromagnetic Welding of Thermoplastics and Specific Design Criteria with Emphasis on Polypropylene*, ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

Electrofusion Welding

Himont: PP (reinforcement: glass fiber)

The suitability of using resistance heated fusion bonding to join glass reinforced polypropylene (GRPP) was demonstrated. C-scans and micrographs of the welded regions showed uniformity throughout the majority of bond areas, which represented a variety of process conditions. Shear strengths of 17.0 MPa (2470 psi) were obtained, with process times of less than two minutes.

The fundamental process-performance relationships were established for resistance welded GRPP joints. Relatively low pressures, temperatures, power levels and process times will yield strong bonds, even with little or no adhesion between the heating element (expanded stainless steel foil) and the polymer. The relationship between processing and performance could be inferred from the lap shear data. Temperatures 10 to 15 percent above the melt temperature coupled with low power and pressure, and short dwell times are conducive to uniform welds, as the C-scans and optical micrographs revealed. In the single lap configuration, these processing conditions were sufficient to promote failure into the bulk adherends away from the interface. The shore beam shear tests reinforced this observation. Also, the treatment of the heating element was revealed to be of critical importance.

Reference: McBride, M.G., McKnight, S.H., Gillespie, J.W., *Joining of Short Fiber Glass Reinforced Polypropylene Using Resistance Heated Fusion Bonding*, ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

Infrared Welding

PP

A new infrared welding machine has been developed, offering a range of advantages over existing butt fusion welding equipment. These include: contact free heating, reducing the risk of contamination on the joining face; joining distance control of the fusion process, resulting in high reproducibility and high weld quality; and the absence of the equalization process, significantly improving the bead geometry and weld strength.

Experiments have shown that a range of welding parameters can be used to reach the maximum weld quality, with the melt depth and joining distance being the determining parameters. The melt depth is fixed by the energy going into the joint, and this is a function of: nature of heater, temperature, exposure time, geometry of the welding assembly and the polymer to be melted.

The mechanical testing conducted on the high quality infrared welds has shown that the welding factors achieved for polypropylene when tested at -40°C were greater than 0.9.

Reference: Taylor, N.S., Klaiber, F., Wermelinger, J., *Assessment of PP and PVDF Joints Made by a New Infrared Joining System*, ANTEC 1993, conference proceedings - Society of Plastics Engineers, 1993.

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IR welding is faster than hot plate welding and it produces joint strengths that are equal to the bulk strength. For hot plate welding using a heating time of 40 seconds, a changeover time of 0.5 seconds, and a weld time of 40 seconds the joint strength was 85% of the bulk strength. For IR welding with a heating time of 11 seconds, changeover time of 0.8 seconds, and a hold time of 11 seconds, the joint strength was equal to the bulk strength (33 MPa). Therefore, for IR welding the total cycle time was only 23 seconds compared with 80 seconds for hot plate welding.

There are optimal heating times and pressures to achieve the highest joint strengths. Reducing or increasing the heating time and welding pressure from optimum decreases the weld strength. For optimal welding, the changeover time should be kept as short as possible. Increasing the heating distance has the effect of decreasing the energy density at the surface thereby lengthening the cycle time. The microstructure that develops in the weld zone is similar to that observed in hot plate welding. It can be divided into three regions, a bulk material region, a flow region, and a region of small spherulites at the weld center. In general IR welding produces excellent joints with very short cycle times.

Reference: Chen, Y.S., Benatar, A., *Infrared Welding of Polypropylene*, ANTEC 1995, conference proceedings - Society of Plastics Engineers, 1995.

Laser Welding

PP

Low power CO_2 lasers have the capability of joining thin (<0.2 mm) plastic sheets in lap and cut/ seal configurations at high speeds (50 m/min). Applications could include high speed packaging where a non-contact, flexible, computer controlled system would have advantages over ultrasonic, dielectric and heat sealing techniques. The Nd:YAG lasers, with the lower absorption capabilities of the shorter wavelength, have the potential to be applied to joining plastics in the thickness range of 0.2-2.0 mm in lap and butt joint configurations. Benefits include low distortion and low general heat input. Differences in the melting of the plastic materials and the effect of pigmentation with Nd:YAG lasers have been noted and must be examined further.

Table 56.1: Summary of laser weld conditions and tensile properties for polypropylene joints.

Material			Laser Conditions			Tensile Properties	
Type	Thickness, mm	Joint type	Type	Power, W	Speed, m/min	% of parent	Failure mode
PP	0.2	lap	CO ₂	100	51	98	parent
PP	0.2	lap	Nd:YAG	80	0.2	70	weld
PP	2.0	butt	Nd:YAG	80	0.1	30	weld

Reference: Jones, I.A., Taylor, N.S., *High Speed Welding of Plastics Using Lasers*, ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

PP

Under optimum welding conditions, laser welding of polypropylene produces joints with strengths (33.3 ± 0.7 MPa) and elongations equal to the bulk material. In those cases, failure usually occurred outside the weld region. Among the welding parameters studied (power, beam offset from the focal point being on the tip surface of the specimen, shielding gas flow rate, welding pressure, and travel speed), laser beam offset (power density) and welding pressure showed the most significant effect on the joint strength. Increasing beam offset while decreasing power density increased the joint strength all the way to the highest offset tested. For PP there existed an optimum pressure for achieving the highest joint strength. The effect of power, travel speed and shielding gas flow rate on joint strength was very small as long as the interface could be cut in one pass. Generally, laser welding of PP was very fast and required no pre-welding preparations.

Reference: Ou, B.S., Benatar, A., Albright, C.W., *Laser Welding of Polyethylene and Polypropylene Plates*, ANTEC 1992, conference proceedings - Society of Plastics Engineers, 1992.

Molded-in Inserts

Shell Chemical: Shell KM6100

The purpose of this study was to answer two questions concerning the pull-out resistance of molded-in threaded brass inserts in polypropylene. How sensitive is the pull-out resistance of molded-in threaded inserts to changes in processing conditions? And do internal lubricants significantly reduce the holding power of molded in threaded inserts?

The base resin was polypropylene homopolymer, natural, Shell KM6100. Control processing conditions were: nozzle temperature - 200°C, front zone - 200°C, rear zone - 150°C, injection time - 10 seconds, injection speed - maximum, cooling time - 25 seconds, injection pressure - 34.5 MPa (5000 psi), mold cool - 18°C, and insert temperature - 22°C. In addition to the base resin, the effect of compounding the polypropylene with 3 different lubricants was evaluated, including 1% Epolene wax (low molecular weight polyethylene); 0.3% calcium stearate and 0.25% Mold Wiz internal lubricant, INT-33A manufactured by Axel Plastics Research Labs, Inc.

The holding power for the control group was 183.5 kg. Increasing the injection pressure to 69.0 MPa (10,000 psi) decreased pull-out resistance by 13.5 kg. Decreasing pressure to 14.5 MPa (2100 psi) decreased holding power by 18.0 kg. Increasing injection time to 20 seconds reduced holding power by 6.0 kg, while decreasing injection time to 2 seconds reduced holding power by 18.0 kg. These significant effects were due to under and over pressurization, and under and over packing. Increasing the insert temperature to 95°C reduced holding power by 19 kg. These results indicate that the pull-out resistance of the inserts was sensitive to the selected changes in pressure, injection time and insert temperature.

Both epolene wax and calcium stearate caused a highly significant reduction in pull-out resistance, lowering it by 29 kg and 37 kg respectively. The lubricants caused the inserts to slip more easily from the surrounding plastic. The decrease in pull-out resistance caused by the Mold Wiz material was only 9.5 kg.

Reference: Lokensgard, E., *Effects of Process Conditions and Internal Lubricants on the Pull-Out Resistance of Threaded Inserts in Polypropylene*, ANTEC 1994, conference proceedings - Society of Plastics Engineers, 1994.

Shell Chemical: Shell KM6100

The purpose of this study was to answer one question: How does time lapse affect the holding power of molded-in threaded brass inserts in polypropylene? To answer the question, samples were injection molded with inserts and tested in tension after 1, 10, 50, 100, 200, 500 and 1000 hours.

The results indicated that the pull out resistance increased as the time increased (from 2110 N for 1 hour to 2435 N for 1000 hours). At lower times, the changes were greatest, and as the time lapse increased, the changes in pull-out resistance became less. It might be expected that the resistance would increase to some point, and then level off. However, at 1000 hours, the data did not indicate a clear point of inflection. The effects of shrinkage continue for extended periods of time. This might shed some doubt on the utility of a uniform 40 hour wait between molding and testing, as is common in several ASTM tests.

Reference: Lokensgard, E., *Time Lapse Effects on Pull-Out Resistance of Threaded Inserts in Polypropylene*, ANTEC 1995, conference proceedings - Society of Plastics Engineers, 1995.

Adhesive and Solvent Bonding

Hoechst AG: Hostacom (reinforcement: glass fiber)

Because of the high chemical resistance of Hostacom's PP matrix, no surface attack takes place at room temperature on molded parts in contact with solvents so that - unless the surface is pretreated - only pressure-sensitive adhesives can be used. Surface pretreatment brings about a considerable improvement in joint strength. It can be carried out in various ways.

- a primer (for example Herberts R 47 509),
- flame treatment with a very oxygen-rich burner flame,
- electrical surface discharge treatment (corona),
- dipping in a chromosulphuric acid bath.

Table 56.2: Adhesive systems for bonding parts made from Hostacom polypropylene

Type of adhesive	Basis
Pressure-sensitive adhesives	pressure-sensitive adhesive solutions.
	pressure-sensitive adhesive dispersions.
Contact adhesives	synthetic rubber, polyurethane.
Two-pack adhesives	epoxy resin, polyurethane, phenolic resin/synthetic rubber
Hot-melt adhesives	vinyl copolymers.

Reference: *Hostacom Reinforced Polypropylene*, supplier design guide (B115BRE9072/046) - Hoechst AG, 1992.

Adhesive Bonding

Himont: Profax 6323

A study was conducted to test for bond strength on a representative matrix of commonly used plastics and the adhesives best suited to them. For many of the plastics evaluated, the effect of polymer composition on bond strength was evaluated by compounding plastic formulations with each of the most commonly used additives and fillers for that plastic; common grades were used for the remaining resins. The effect of each additive and filler was determined by comparing the bond strength achieved with the specially compounded formulations to that of the neat plastic. In addition, the effect of surface roughening and chemical treatment of the plastic surface on bond strength was examined.

The block-shear (ASTM D 4501) test was chosen as the test method because it places the load on a thicker section of the test specimen that can withstand higher loads before experiencing substrate failure. In addition, the geometry of the test specimens and the block-shear fixture helps minimize peel and cleavage forces in the joint. How well the block-shear test method reflects the stresses that an adhesively bonded joint will experience in real world applications should be considered. Also, limitations on the data due to the variety of additives and fillers used by different companies should not be ignored.

Prism 401, used in conjunction with Prism Primer 770, achieved the highest bond strengths on PP, typically substrate failure. Black Max 380, a rubber toughened cyanoacrylate adhesive, Prism 401 and Super Bonder 414, both cyanoacrylate adhesives, Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105, a light curing acrylic adhesive, all performed poorly on unprimed, unabraded PP.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, resulted in a dramatic, statistically significant increase in the bond strengths achieved on PP, typically substrate failure. Surface roughening resulted in either no effect or a statistically significant increase in the bond strengths achieved on PP.

Other Information

Polypropylene is compatible with all Loctite adhesives, sealants, primers, and activators. Recommended surface cleaners are isopropyl alcohol and ODC Free Cleaner 7070.

Table 56.3: Shear strengths of PP to PP adhesive bonds made using adhesives available from Loctite Corporation. Values are given in psi and (MPa).^{a,c}

Plastic Material Composition (Himont Profax 6323)	Loctite Adhesive					
	Black Max 380 rubber toughened cyanoacrylate (200 cP)	Prism 401 surface insensitive ethyl cyanoacrylate (100 cP)	Prism 401/ Prism Primer 770 polyolefin primer for cyanoacrylate	Super Bonder 414 general purpose cyanoacrylate (110 cP)	Depend 330 two-part no-mix acrylic	Loctite 3105 light cure acrylic (300 cP)
Unfilled resin 5 rms	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
Roughened 26 rms	50 (0.3)	550 (3.8)	1300 (9.0)	300 (2.1)	200 (1.4)	450 (3.1)
Antioxidant 0.1% Irganox 1010 0.3% Cyanox STDP	50 (0.3)	250 (1.7)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
UV stabilizer 0.5% Cyasorb UV 531	50 (0.3)	50 (0.3)	>1950 ^b (13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
Impact modifier 9% Novalene EPDM	50 (0.3)	150 (1.0)	>1650 ^b (>11.4) ^b	200 (1.4)	200 (1.4)	100 (0.7)
Flame retardant 9% PE-68 4% Antimony oxide	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	250 (1.7)
Smoke suppressant 13% Firebrake ZB	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
Lubricant 0.1% Calcium stearate 24-26	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
Filler 20% Cimpact 600 Talc	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	100 (0.7)	200 (1.4)	100 (0.7)
Colorant 0.1% Walchung Red RT-428-D	50 (0.3)	50 (0.3)	>1950 ^b (>13.5) ^b	50 (0.3)	200 (1.4)	100 (0.7)
Antistatic 0.2% Armostat 475	50 (0.3)	200 (1.4)	>1950 ^b (>13.5) ^b	200 (1.4)	200 (1.4)	100 (0.7)

^a All testing was done according to the block shear method (ASTM D4501).

^b Due to the severe deformation of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

^c For more information on data presented in this table, contact Loctite Corporation at 800-562-8483 (1-800-LOCTITE). Request the "Design Guide for Bonding Plastics."

Reference: *The Loctite Design Guide for Bonding Plastics*, supplier design guide (LT-2197) - Loctite Corporation.