An Update on Automation Technology

For

Latex Dip Molded Products and Coatings

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By

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Background

The process called "dip molding" has its roots in the USA and United Kingdom. Dip molding involves the lowering of a form or mandrel into a polymer bath, attracting a thin liquid film deposition onto the form or mandrel after rising from the bath. The film is dried for subsequent removal from the form, after which the form or mandrel returns to the start of the process. The dip molding process can take as few as 4 steps, or as many as over 50 steps to complete a dipping cycle.

In addition to the main polymer dip, other tanks or steps are employed on the dipping line to finish the product including form cleaning stations, leaching tanks, powder application stations, mold release stations, coagulant tanks, polymer coatings, ring rolling, rough texturing, cooling stations, and ovens. Most applications from the known beginning of dip molding in the 1930's until 1985, involved the use of natural rubber latex or polyvinylchloride compounds. Until 1985, dip molding was a slow growth industry residing primarily in the USA and Europe, in an oligopoly type of industry with few players.

Advantages

Dip molding found its advantages in high volume production of components requiring very consistent wall thickness performance for thin film products such as latex gloves, latex toy balloons and latex condoms, and for thicker film products such as urinary catheters, which demand a soft, flexible material for performance and patient comfort.

Furthermore, the performance of natural rubber for products such as breathing bags, toy balloons, and urinary catheters makes the process of dip molding a very competitive one, in that tooling costs are generally low, and new product designs can be introduced quickly and inexpensively. Complex tubular products such as a Foley catheter can be made successfully with minimal tooling costs using the process of dipping.

The dip molding industry grew measurably by 1986 after the medical community recognized the HIV virus as a major threat to mankind. Because of this disease, the need for disposable hand protection grew measurably overnight, and manufacturers began to quickly tool up for more production. The latex condom industry experienced the same growth pattern during that time, albeit not as high a growth rate as that of latex gloves. As part of this manufacturing trend, a heightened concentration on manufacturing automation was implemented by the larger manufacturers of latex products used for human protection. In attempt to reduce manufacturing cost, major US and European
manufacturers began focusing their factory growth expansion in Southeast Asia and other latex producing countries.

**Latex Allergies**

In 1992, the general awareness of latex anaphylactic shock entered the scene, as documented cases of latex allergies, some severe enough to cause major medical problems for some individuals, grew at an alarming rate. Some users of latex gloves found themselves to be allergic to the donning powder applied to the glove as well. It was estimated that anywhere from 2% to 10% of the population had some form of allergy related to latex products exposure. The industry and the FDA was forced to respond to the issue in efforts to make thin film barrier products safe for consumer use.

The response by the dip molding industry was threefold;

1. A move was made to remove the donning powders from the end product. Powder-free gloves were introduced to the market place, accomplished through post-chlorination procedures which removed process powders and made for a frictionless surface on the latex product.

2. A move was made to reduce extractable proteins from the natural rubber latex products through on-line protein removal stations in the dipping process. The same effort to reduce proteins was implemented into the latex centrifuging procedure, accomplished by multiple cycles of the centrifuging process.

3. A growth cycle started in the dip molding industry for non-hevea latex products. Polymers such as polyvinyl-chloride (PVC), polyurethane, nitrile latex, chloroprene latex, and styrene butadiene were suddenly designed and formulated to compete against natural rubber latex. All of these polymers had the advantage of being protein-free materials, and considered more suitable for people suffering from latex allergies.

Over the last ten years, processes still employing natural rubber latex have greatly improved quality associated with protein control, and thus scrutiny and criticism of natural rubber as a medical product has diminished. Also, much of the litigation placed against latex product manufacturers was dismissed in US courts, thus slowing the trend for new litigation. However, during the years whereby latex underwent strong scrutiny, some medical facilities banned latex altogether, and thus today the disposable glove market in particular, shows strong market presence for nitrile gloves and PVC gloves. Chloroprene latex glove suppliers have also managed to secure market share and chloroprene is now the material of choice over latex and all other polymers for use in re-breather bags.
The primary reasons for employing dip molding as a process are:

1. An accurate method of manufacturing thin wall barrier type products, with impenetrable film barrier achieved using films as thin as 0.50 mm.
2. For high volume production (6,000 to 60,000 pieces per hour), no other molding process can out-perform dip molding for speed and productivity.
3. Generating tooling is fast and cost effective.
4. Color changeover (i.e. toy balloons) is fast and cost effective.

Dip Coating

The process of dipping also is employed to routinely coat articles and substrate materials. The use of lattices in this manner is employed to coat gloves of different fabrics such as cotton, nylon, polyester, etc. This process is quite common and substantial in a number of plants globally, particularly for use in producing industrial and consumer work gloves.

In the medical glove and medical device sector, another type of dip coating has become prevalent; that of coating the device with lubricious or anti-microbial coatings. The use of this polymer technology in manufacturing natural and synthetic latex products began its impressive growth pattern by 1995 after the latex allergy awareness patterns came on the scene. It was determined at that time, that latex donning powders could increase the spread of latex allergies through airborne powder created during glove donning and glove removal. Powder used on gloves often carried residual protein from the natural rubber latex article. The use of polymer coatings as the donning agent offered an alternative powderfree choice to compete against chlorinated latex products.

Stages of Automation Awareness

Automation awareness usually becomes a focus of manufacturing firms between the early growth and late growth timing pattern of a product’s life cycle. Once the product grows to the level of “maturity”, there are typically many competitors seeking to secure market share. At this stage, firms typically will seek manufacturing automation solutions to reduce cost, increase margin, and gain or retain market share.
The latex products manufacturing industry, in general, is currently in the “maturity” phase. However, latex disposable products still continue to grow at rates of between 4% and 10% annually, due to the following factors:

1. Increasing global population.
2. Increasing awareness of healthcare and disease prevention in developing nations.
3. Increasing applications and usage occurrences in health and protection in developed nations.

This paper’s intent is to report on present automation trends in the industry and on specific types of technology that are currently the focus of attention for many of the world’s top manufacturers of latex dip moldings and latex coated products.

Interestingly, the automation trend in the United States for latex processing has slowed since the turn of the century, primarily due to the relocation of virtually every disposable latex glove manufacturing plant to Asia during this time. Two condom manufacturers remain on US soil, but high levels of automation for this product have already been achieved dating back a few decades, even though selected opportunities exist to further automate this process. Furthermore, there are fewer competitors in the US latex condom industry today as compared to gloves, so pricing pressure is not as intense for condom products in the United States.

The most common business model for latex dip molders in the US today (in number of manufacturers, not sales volume) is the manufacturer of specialty-dipped articles in low
volumes (from 20 pieces to 10,000 pieces orders). Automation trends in this sector are in turn slow, if at times non-existent. However, interest by these companies in implementing manufacturing improvements through automation and machine design become stronger when the business model makes sense (repeat orders, growing markets, and evidence of pricing pressures in the marketplace.)

In Asia (primarily Malaysia, Indonesia, Thailand, China, India, Vietnam, and Sri Lanka), where the majority of glove and condom manufacturing resides, the automation trend is still strong as firms seek technology solutions for faster lines, automatic product removal, and improved process control. This trend is even present in ultra-low labor cost countries such as China and Vietnam, as will be shown later in this paper.

Some of the latest automation technologies being implemented or being considered on the part of latex dip molders are highlighted in this presentation. It is the intent of the writer to present compelling evidence that despite current global economic woes, and despite some latex products being at the mature product life cycle stage, latex product dip-molding firms continue to automate where sensible to optimize productivity and industry competitiveness.

POLYMER MANAGEMENT

A key area of cost control resides in proper management of compounded lattices in the manufacturing operation. Two current trends and industry interest levels dominate discussion this area of automation techniques for increase productivity.

The first is that of dip tank design and management. Despite the presence of impressive dip tank technology dating back as far as the 1980’s, it is surprising to discover how few firms take advantage of the technology available in the marketplace. The trend toward awareness has picked up however, over the last few years.
The use of properly designed dip tanks for latex formulations can increase tank turnover, improve circulation and polymer solution consistency, and increase product quality yield. This technology resides today not only for large scale plants, but even for use in the manufacture of small medical devices for dip tanks holding as little as 10 liters of solution. One common design technique employed to optimize latex circulation is the use of false bottom technology. Designed properly, the flow properties achieved can greatly enhance product quality and extend latex tank life. Fewer shutdowns are needed for tank cleaning with the use of correctly designed false bottom technology.

Time nor intent of this paper does not permit a detailed discussion on all design features a latex dip tank can employ to optimize performance, but key design points include the following:

- Flow baffles and false bottom flow technology
- Temperature management
Circulation techniques including avoidance of latex shear
- Level control
- Tank “top-off” techniques
- Mixer blade design
- Specific gravity and density management

The second area of polymer automation discussion this paper will address in detail is that of **viscosity control**. This technology has been popular for use with solvent-based polymers such as silicones, polyurethanes, butyl latex, and many thermoplastic elastomers. These solutions tend to increase in viscosity during the dipping operation due to solvent out-gassing that occurs naturally. Without correction, film pickup will increase and articles will quickly fall outside of acceptable film thickness range.

Viscosity is the resistance of a fluid to flow. The classic definition is the ratio of shear stress to shear rate. The common metric unit of absolute viscosity is the poise, which is defined as the force in dynes to move a surface one square centimeter in area past a parallel surface at a speed of one centimeter per second, with the surfaces separated by a fluid film one centimeter thick.

In any fluid, there is always some attractive force between the atoms or molecules. As the fluid molecules slide past each other they experience friction, just like the friction between two solid surfaces. If the fluid is to flow, enough energy must be supplied to overcome this friction. In other words, one must “push” it hard enough to get it moving.

One may not have to push very hard. When we walk, the air flows around our bodies without our having to make conscious effort. Stirring a cup of coffee is not especially exhausting. Some fluids, however, resist attempts to make them flow. Try to stir molasses as quickly as one would stir one’s coffee and the difference will be quickly felt.

Everyone knows that molasses is “thicker” or “more viscous” than water. A “viscous” fluid is thick and sticky, like molasses or glue. It resists attempts to make it flow. Viscosity is the amount of this resistance to flow. It is a measure of the effort you have to make to “shear” the fluid — to overcome the friction between layers of molecules.

Fluids have lower viscosity when they are hot. Atoms and molecules have more energy at higher temperatures. They move faster, overcoming the friction, so the viscosity falls.

The English physicist Sir Isaac Newton (1642 - 1727) was the first to define viscosity scientifically. He derived a mathematical formula relating the viscosity to the resistive (drag) force experienced by a thin plate “cutting” its way (“shearing”) through the fluid.
In the fields of dip molding and dip coating, viscosity measurement is often conducted only at the compounding area. Once a dipping solution is confirmed and approved, the production department often will not continue viscosity measurement efforts. If viscosity is measured for most lattices, a Zahn cup is the normal instrument to employ, one which does not perform well with heavier fluids.

Fortunately, automated technology that is reliable and repeatable now exists in the field of viscosity measurement.

Some lattices demand the use of a viscosity builder to increase compound thickness before dipping. The combination of adequate dip tank design and viscosity control technologies can be employed to extend tank life and increase product yield.
MOTION CONTROL

Batch dipping systems should be designed with proper repeatable motion controllers and conveyance systems for pallet transfer. A recent innovation in the industry employs the use of wireless induction power transfer technology, which has the advantage of continuing mold motion(s) during pallet transfer, resulting in improved film uniformity for thin films.

Wireless power induction was introduced to public sector originally in the form of electric toothbrushes. An electric toothbrush contains coils or loops in the toothbrush handle as well as in the base recharging unit. Because of their constant exposure to water, electric toothbrushes have to use inductive coupling as a means of recharging their batteries.

Inductive coupling involves the use of magnetic fields to stimulate the movement of current through a wire. A current moving through a wire generates a magnetic field around it and vice versa. Thus, to generate a current through a wire, there needs to be a constantly changing magnetic field.

(Figure 5 – The principle of contactless energy transfer)

Contactless energy transfer systems can be used with dip molding equipment today. The electromagnetic connection is made via an air gap and is not subject to wear, rendering it generally maintenance-free.
The other primary benefit in using induction power technology is that form motion can continue while the pallet of forms is being transferred to the next station. To optimize product yield from the dip machine, one needs to optimize number of dips made by the dipping manipulator. For many processes, after the dip is made, the pallet then hovers over the dip tank, and performs a rotation profile over the dip tank, until the latex is gelled sufficiently and ceases movement on the dipping form.

With induction power technology, the pallet can immediately begin transfer to the next station for continuance of form rotate form axial spin motions as needed. This frees up the dip station to continue the dipping process for the next pallet of forms, and in turn, increases dip machine yield.

The cost of the technology can be made justifiable through increase production throughput, and improved quality. Each application of course should be evaluated for cost-benefit before employing the technology.
DIP COATING OF TUBES AND CATHETERS

Medical devices today for many applications mandate the application of precise coating height and coating weight. Coatings for purposes of lubricity and anti-microbial features have grown to be common for many types of catheters, many of which are still manufactured from natural rubber latex and polyisoprene latex.

For some of these applications, the coating must be applied to the entire inside diameter of the tube. At times this is done in tandem with an outside diameter coating, and at times the specification calls for coating of the inside diameter only, through either the tube opening at the bottom of the piece, or a lumen opening.

Coatings can be applied in this manner using properly designed vacuum systems, in tandem with programmable controllers to control coating height for the inside diameter of very small lumen shafts or tube openings.
A gasket interface located between pallet and pallet fixture provides the seal necessary when pressure and/or vacuum are applied to the pallet fixture cavity.

The cavity includes a polymer displacement block to minimize volume and improve reaction time when vacuum is applied. Independent ports are supplied on the pallet fixture, one supplied for vacuum and one for pressure. An electric vacuum pump then interconnects to the pallet fixture and will create the vacuum in the pallet fixture cavity. A sensor monitors and controls the amount of vacuum generated in the pallet fixture cavity.

The adjustment of the vacuum can vary the level of the solution drawn into the lumen of the catheters. The catheters connected to the pallets can each be supplied with the same vacuum and/or pressure supplied to the cavity, therefore, it is implied that each will draw the same amount of fluid into the lumen, assuming the lumen diameters are consistent and no obstructions are present.

Similarly precision regulators and flow control sets can be provided to control pressurized air or other gas such as nitrogen that can be supplied to the pallet fixture to evacuate excess solution inside the catheter lumens. Solenoid valves can control the supply of the pressurized air/gas to the pallet fixture.
AUTOMATIC PRODUCT REMOVAL (ASIA TREND)

Most high speed, high volume production dipping lines that remain in the United States have long been equipped with automatic product removal technology. This would include the production of the following latex products:

- Gloves
- Condoms
- Balloons
- Breathing bags
- Single lumen catheters

An exception to this would be products of complex shape such as Foley catheters.

In the year 2000, automatic product removal technology for disposable gloves started finding its way into Asia, particularly in Malaysia, Indonesia, and Thailand. The technology was first developed in the US, and employed in several factories prior to the turn of the century. The technology employed the use of compressed air with a simple mechanical device synchronized to the dip line speed, to reverse the latex glove from the mold.

(Figure 9 – US design for automatic glove removal technology for NR latex gloves; Howe et al US patent 5,776,520)
Growing labor costs resulting from the need of imported labor made this technology desirable and justifiable in Malaysia and Thailand after the year 2000, and the Asian manufacturers were able to successfully implement this US based technology from 2000 to 2005 to their factories for natural rubber gloves. Today, most natural rubber glove plants in this region employ automated or semi-automated product removal technology on all of their glove lines.

The most commonly used technology employs the use of a pair of metal strips that collapse upon and secure the glove fingers to the mold. A series of air nozzles deliver high velocity air to loosen the cuff from the mold, which begins the inversion process. The cuff inverts over the secured fingers, and hangs below the fingers once the air delivery process is completed. The containment strips are then actuated away from the latex film, and a pair of opposite-spin brushes or rollers pinch the cuff, and remove the glove completely from the mold into a collection tote or upon a conveyor for transfer to the inspection or packing area. The technology worked well with disposable natural rubber gloves, but was not as successful with nitrile latex gloves that were growing in consumption by the year 2000. Larger firms have also successfully automated downstream packing for products such as gloves and condoms.

Today, the growth of nitrile latex glove plants in China, along with their continuing dominant role as the leading supplier of PVC gloves, has resulted in some implementation of automatic glove product removal technology there. Despite lower labor costs in this region than that of Southeast Asia, the growth of automatic product removal technology is still dynamic. The implementation of more complex mechanical glove removal techniques (over the use of primarily compressed air) makes possible more
successful “stripping” performance for the less elastic nitrile and PVC gloves. Both disposable PVC and nitrile gloves today are more commonly produced in China as compared to disposable natural rubber gloves still dominated by Malaysia, Thailand, and Indonesia.

This photograph of automatic product removal technology was taken recently at a disposable glove plant in China. The technique shown has roots dating back to 1990 in Europe for use with the manufacture of dip molded household gloves (see figure 12), and is currently the most common technology employed for use for not only disposable nitrile and chloroprene latex gloves, but even for disposable PVC gloves.

Glove manufacturers are seeking every possible competitive advantage in a market that is known for tight margins, and strong competition; hence, the demand for use of automatic product removal technology in the lowest of all labor cost countries such as China and Vietnam.
PACKAGING – LATEX GLOVES

For years, surgical glove packing technology has been commonly employed to reduce labor in this downstream operation. However, the most recent advance in latex products packing technology addresses the labor-heavy examination glove packing room. Disposable examination gloves are commonly packed into cardboard dispenser boxes, which vary in glove count per box dependent upon purpose and glove size. The typical packing procedure for disposable gloves includes numerous manual process steps, and represents the area of exam glove plants where labor need is presently the highest. Recent advances in technology has resulted in successful implementation of fully automated systems for glove packing, capable of receiving bulk, random delivery of gloves, automatically counting, orienting, and packing. This technology is capable of automatically layer packing, the preferred method for non-sterile glove packing today.

Doka Asia Sdn. Bhd. in Malaysia offers this technology as shown above and reports the typical automated procedure to occur as follows:
- Gloves are automatically or manually half stripped from the former
- Half stripped gloves (still hanging on fingers) are taken over by the machine’s Glove Release Mechanism
- From there gloves are transferred to the Glove Layering Unit where the gloves are layered piece by piece (to ensure easy dispensing process for final glove customer/user)
- After the desired number of gloves has been reached the glove stack is transferred to a glove compression unit, where excess air is pressed out of the gloves
- After that the compressed gloves are automatically inserted into an open cardboard dispenser box by the machine’s boxing Unit
- From there the final dispenser box is transferred to a stacker magazine for collection.

Automatic cardboard box opening is also reportedly offered with the technology, if applicable.

It is reported that the glove processing rate for this new technology is approximately 110 gloves per minute or one packed dispenser box (100-count) in slightly less than one minute, each.

This recent technology advance greatly reduces labor content in the downstream packing operations, resulting in impressive labor savings through engineered automation.

**SUMMARY**

The use of properly designed manufacturing automation still plays a major role in the manufacture of latex dip molded and dip coated articles. The globalization of this industry began back in the early 1980’s, and continues at a high rate today, with a particularly strong trend in Asia.

The use of coatings with latex articles has also provided opportunities for new automation designs and application techniques, a trend which is expected to continue globally over the next several years.
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