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RESEARCH ARTICLE

PRACTICAL ANALYSIS OF BONDING FAILURE REASONS IN FOOTWEAR PRODUCTION

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ABSTRACT

The shoe industry demands an impressive array of adhesives due to variations in materials, processes, types of footwear, and seasonal design changes. Equally impressive is the performance demands placed on adhesives in this industry. These include a high degree of bond strength to resist numerous repetitions of bending, straightening, compressing, recovering, rubbing, and friction. The bond strength must also not be affected by rain, snow, wind, ultraviolet light, temperature changes, and whatever other elements to which the shoe will be exposed. In this review identify the adhesives bonding failure reasons in footwear processing. Failure reasons such as poor adhesive selection for processing, adhesive application problems, upper bottom poor skiving, poor lasing. Improper buffing process, adhesives improper applying methods , hot oven temperature control , improper sole attaching and sole pressing. In addition to providing high performance properties and durability, the adhesives and bonding processes that are used in the footwear industry must also offer good early strength and workability for fast and efficient production. The adhesive bond must be invisible or at least aesthetically pleasing to the shoe's design. And more recently, an additional imposing set of requirements has been placed on the shoe manufacturers - formulations and processes must be environmentally friendly and hazard free. Now days all footwear industry used for Water based adhesives use water as the carrier fluid, with the adhesive particles suspended in water, reducing the adhesive's viscosity so that it can be applied to various substrates at varying thicknesses. Evaporation of the carrier fluid during the set and cure stages typically occurs in large ovens. Evaporation and cure also can take place in the open under ambient, non-thermal conditions. It is important to note that not all water based adhesives are 100% solvent-free, but may contain some VOCs as assistants to the water base for proper viscosity or fluid control. Water based adhesives have been available since the 1970s. They are formulated from rubber compounds (as the base material), with various additives such as synthetic hydrocarbon resins or pine sap derivatives to increase strength characteristics. The performance of solvent-based adhesives is largely determined by the polymer system in the formulation. The choice of adhesive type depends on the specific substrates and environmental resistance needed – temperature resistance, oil and plasticizer resistance, etc. Most solvent based adhesives contain flammable solvents which require proper precautions for safe handling. In addition, many organic solvents are regulated due to environmental concerns with emissions. Within each type of solvent based adhesive, formulations are available to match the application requirements of the process – brush, roll, bead or ribbon, spray. Once the adhesive is applied, solvent evaporates relatively quickly causing an increase in viscosity of the adhesive film. Bonds can be made immediately after adhesive application or after some solvent has evaporated but before the adhesive has dried to the point.

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INTRODUCTION

An adhesive is a material that is applied to the surfaces to join them permanently by adhesion bonding process. There are two principles types of adhesive bonding structural and Non-structural adhesives bonding is bonding for application in which the adherents (the object being bonded) may experience large stresses up to their yield point. A structural bond has been defined as having a stear strength greater than 7Mpa addition to significant resistance to aging Non structural adhesives are not required to support substantial load but merely hold light weight material in place (Adhesive in the footwear industry, 2015). This types of adhesives sometimes called a Holding adhesives pressure sensitive tapes and packing adhesives are examples of structural adhesives. In footwear production nowadays lot of adhesives used for bonding purposes such as glue, Latex, cement ,primer, Hot melt adhesives, PU adhesives is the very important adhesives. Over the last 40 years there has been a major change in soling materials used for footwear trade. Leather has traditional soling materials for footwears but 1980 only about 5% of shoes have leather soles, now days most sole are made of rubber or plastic, which are classed as synthetic soling materials. So new soling materials needs new types of adhesion methods and adhesion techniques with different types of upper materials. Now days Rubber sole, TPR, PVC, and PU soles are mostly used in all types' footwear industry. Sole bonding strength is very important property in footwear making process, if the sole bond test is failure totally footwear lost their customer values.

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This bonding strength based on the upper skiving, lasting, buffing, scouring process, outsole buffing, adhesive applying methods, hot oven temperature, Outsole attaching, and sole pressing standard methods. In each one operation is not proper totally adhesive bonding strength is failure. So in footwear production having lot quality focus in this part to improve finished product quality. This review identify the footwear production inline bonding test failure reasons and prevention methods .Today adhesives material that glue, Latex, cements, Mucilage, Resins, Paste ,thermoplastic adhesives, synthetic adhesives nitrocellulose, cellulose esters, is the best adhesives (Paiva *et al*., 2013).

Literature reviews

Most of the thermoplastic resins were soluble in organic solvents and were used as solvents adhesives, adhesives for different materials PVC, thermoplastic developed in 1925 is used today in solvent formation to bond PVC articles as loaded fabrics, films, foams, pipes, polyurethane adhesives are polymer produced by addition reaction but poly isocyanides, hydroxyl rich compounds groups such as Glycol, polester, polyethele. Today PU adhesives are available as solvent based –moisture adhesives, thermoplastic, Hot melts, and thermosetting systems are emulsion (Impact of Microwave energy and Leuconate Hardness on the adhesive joint strength, 2014). Now days most developed countries natural adhesives dominate the market trade because they are very cheap prices than synthetic based adhesives and they perform the intended friction. Natural rubber solvent solution adhesives are widely used throughout the world as general purposes adhesives. In footwear industry commonly used for Glue, Latex, Cement and Primer, PU adhesives, Hot melts adhesive for footwear production purposes. Adhesive form an important part of leather product and footwears. Adhesives mainly used for leather goods production in two main purposes temporary and permanent joints, most of leather goods require temporary joint while assembly, and they are stitched later to be permanents for the end of the use. Footwear industry adhesives are classified into two types such as 1.water based adhesives 2. Solvent based adhesives. Water based adhesives are Natural rubber latex, synthetic Latex. Vegetable paste. Natural rubbers are a product as milky substances known as Latex. it is obtained from Heveabrasilinsis. Latex is colloidal dispersion of rubber particles in water, normally it is tapped from rubber trees, and it is compound with resins to improve tack effecting, ammonia used as stability agents in this solution. Latex having poor heat resistance and easily sprayed. In footwear production normally latex used for lining attaching, folding, laminating, insole attaching, heel covering process (Solid Adhesives for bonding the sole to the upper in the footwear industry, 1997). Another one synthetic lattices is obtained from emulsion or dispersion of synthetics polymers such as polyvinyl chlorides acetate (PVA), Polychloreprene or PU in water, this types of adhesives mainly used for lining attaching, sock liner attchaing, Toe puff, stiffener attaching. Vegetable paste is made from starch that is a derivatives of starch, this is non flammable and low bonding strength and normally it is used for box leveling purposes.

Solvent based adhesives is prepared from milling latex together with the compounds rubber and dissolving the same in solvent, such as benzene or getones, resins, special tack filler is used for better adhesion bonding strength. Normally it is flammable, good tack but no strength, this is sensitive to oil and organic solvents, footwear industry lining attaching, sock liner, edge folding process. Polychloreprene is synthetic elastomer with many of the property of natural rubber, this is high bonding strength than other base adhesives with easily brush or spray. Footwear production lining attaching process, insole rib attaching, insole, lasting, heel counter attaching is better. Resins and antioxidants used as a ingredients. Next important adhesives Polyurethane (PU) is prepared from di isocyanides having two isocyanides groups is reacted with a idol having two hydroxyl groups. PU adhesives having three categories reactive, hydroxyl solvents, agues dispersion medium. It has good flammable and strong bonding strength, oil resistance characteristics (Sultahn Nasar *et al*., 2006). PU adhesive having high green bonding strength but at least 48 hours needs to reach full strength, difficult to remove if materials are contaminated, ketone and other solvents is used for improve the tacking effect. PU adhesive always flammable and difficult to remove after attaching.

Adhesive bonding strengths having two types 1. Mechanical adhesion 2. Specific adhesion. Many material has visibly rough surfaces, smoothest surfaces having contained microscopic pores. When adhesive is applied in liquid form to the surface, some of its flows into these pores after drying, the adhesive layer will keyed to the materials surfaces rather like two pieces of a zigzag puzzle are properly joined together. Good bonding can be formed to fibrous surfaces between adhesive surrounds the fibers. In most the adhesion bonds there is some degree of mechanical adhesion present PU, Polychloprene, and Latex on leather, fibrous and rubbing soling materials. Specific adhesion when molecules diffuse into becomes intertwined with the molecular and material surfaces. For this happen the attractive forces between adhesive molecules and leather or material surfaces between must be at least as strong as the attraction of adhesive molecules for each other. Footwear industry adhesive having good attraction forces is must for better bonding incase this property is poor adhesive is not suitable for bulk production. Heat performs a similar function when using hot cements and when causing one cement films to coalesce with another after reactivation (Dongho Kim *et al*., 2014). In another types of specific adhesion the molecules in the cements become bounds by strong chemical bonds to molecules in the materials, for this happen there must be specific chemical stresses present in the two bonding surfaces, frequently the material surfaces is made chemically reactive to the cement just before spreading by applying a special primer, for example is the uses of a halogenations agents on thermoplastic rubber before applying PU cements. This articles clarify the adhesion failure in footwear productions and give some implementation techniques to improve overall production quality.

Bonding failure reasons and prevention methods in footwear

1. Poor selection adhesion materials

In footwear production currently meet lot quality issues in each sequences, particularly sole bonding is important property for finished products. Customer like always better finished quality products so each operation should be properly focused in industry. Currently footwear industry used lot of water based and solvent based adhesives , adhesive selection is key point for quality, quality branded adhesives and expiry data and adhesion mechanical and force test certificate is must for all

branded, after that A01 certification and MSDS data sheet should be attached in all packing adhesives delivery challaen. In case if the above standard is not properly focused, in production time we meet lot of bonding failure, so all finished product and manpower and investments also may be meet lot problems. Commonly normal footwear sectors they are not give special attention to material selection, this also important issues in footwear sectors.

2. Improper skiving process

Skiving operator is a critical operation in footwear manufacturing, skiving is done along the edges of the material, so that it can fold and pasted, lasted with easily and accuracy. This skiving operation greatly influences the appearances of the finished shoes. This operation also one of the important role in adhesion bonding strength. A highly skilled operator is required to do skiving as the skill required do skive is high and the same time the opportunity to injure one while skiving is also high rish. This operator must be capable to operate both upper and lower skiving machines and also skilled to perform skiving with accuracy according to the standard specification (Control of the bonding process in a medium technology industry, 1985). This skiver must also cabable to perform the maintenance of the grinder and the skiving disk knife. Skiving is should be proper allowances in lasting margin, side bottom bonding failure be thoroughly controlled. Bottom lasting margin skiving minimum 8-10 MM is standard for normal types of footwears. Skiving area should be fixed Skiving model SOP (standard operation system) and skiving guide. This operation is not focused in footwear production it also leading to adhesive bonding failure problems.

3. Poor hand lasting problem

In footwear production very important operation is lasting, lasting allowances , seaming temperature 90-100 Degree for 8-10 seconds standard procedure are not followed in this area lasted shoes meet bonding failures problems, Toe part and heel part also crooked and overall lasting margin is not uneven after that process outsole marking and buffing also affected. Finally thus the upper meet uneven pasting and attaching .Due to this poor operation is leading to final product finishing appearance. So footwear production inline should be fixed SOP details for every sequence. Hand lasting operator having skill and well knowledge about lasting margins and Assemly procedures.

4. Uneven marking and buffing in assembly area

This process also very important for bonding strength, outsole making area should be thoroughly monitereded such as SOP details, marking machine pressure standard, Buffing ARO wheel emery paper colour managements systems is arranged in this area. Marking is proper allowances both sides after that buffing also easy, without proper marking and buffing totally thus the whole footwear production meet lot up normal quality issues and poor bonding strength. Buffing Area buffing gun Colour SOP systems is must, every one hour buffing grid paper should changed. The above techniques are followed in this sequences bonding failure, poor margin attaching, over attchaing also easily controlled in footwear Assemly lines. Some stichdown and welded construction shoes scouring process also one of the biggest problems in footwear industry, in this area Standard operation systems and marking also very important operation. Adhesion bonding is based on the surface roughness .so overall margin should be properly buffed after that adhesive is attchaced uniformly in overall margins. So bonding failure will control without any difficulties (Brue Barry and Peter Milburn, 2012). Lasted upper buffing is uneven attaching pressure point is more so adhesive is not attached properly. This up normal quality operation is leads to bonding failure problems. Out sole buffing is also another important operation in Assemly lines. Outsole inside attaching margin area 12-15 MM thoroughly buffed with wire buffing machines, incase buffing is uneven attaching also not uniform in overall area. Buffing is properly followed in this part; adhesives are easily penetrated into the rubber pores after oven heating, Outsole attaching is property attached. Sole bonding is not proper standard total production also loss for footwear industry .Customer first see the sold bond test report, after that they will confirm the shipments. All footwear industry if having own sole bond test instruments, and regularly they will check bonding strength property. This articles refer the above quality parameters in the assembly lines for prevent the adhesion sold bond failures.

6. Adhesives uneven applying and oven temperature problems

Adhesive applying area very important sequences in footwear Assemly process. This area colour brush quality management system is must and SOP systems 100% should be followed in this area. Every one hour brush changed, nowadays water baesd cement and primer is used for many footwear industry. Primer and cement is not properly applied overall lasted uppers margins defiantly it will lead to bonding failure problems. Lasting attaching margins knowledge is very must for adhesives applying workers. Oven temperature control and standard curing time is thoroughly followed in Assemly section. Based on the adhesives property, this system is 100% followed. Poor curing time is not suitable for proper outsole attaching, and final adhesive test report also totally failures. Every one hour oven temperature is checked by temperature gun and record is maintained properly in this part, it will control the up normal attaching issues in Assemly lines.

7. Attaching and sole pressing problems

Bottom attaching is major operation in footwear making process, attaching operator having well skilled and well knowledge about attaching margins and bonding property This section work area properly designed and SOP systems is followed. Most of bonding failure reason poor attaching ,So final product lost their export trade due to this unskilled operation. After attaching thus the shoes are treated to sole pressing machines operation, in this area pressing pressure and Time is very important for footwear manufacturing (Supply chain and sustainability solutions for the footwear industry, 2013). Every day two times (morning and afternoon) pressing record is taken by supervisor and got sign from quality engineer. Normally out sole pressing time minimum 1Omins 35-40 kg load for water based adhesives attached Rubber soles, Due to this pressing operation compresses the bottom, sides, and heel of the sole and upper together. To set the bond, the lasted upper with the bottom attached is often placed in a chiller unit. Cooling chiller time is very important for this assembly section, normally rubber sole - cemented adhesives upper cooling time 12-15 Mins, Once out of the chiller unit the shoe is de-lasted by hand or by machine. As per the this review above quality implementation systems is followed in

footwear manufacturing process, adhesives bonding failure problems is easily controlled

RESULTS AND DISCUSSION

This review focus the adhesives bonding failure reasons and prevention methods, Although footwear design does not appear to have changed significantly over the last century, other than to meet the demands of fashion, the techniques used in the manufacture of shoes have undergone revolutionary changes in that time. The construction of modern footwear involves a widespread use of adhesives, the major exceptions being the sewing of uppers and in some cases, the attachment of heels with nails. This has resulted in a reduction in the production times for each item, as well as a reduction in the skill levels required for many of the operations. Of these adhesive joints, probably the most demanding joint is that between the sole and the upper material, and it is this joint that is considered in the forensic study. For regularly used items of footwear, the life expectancy is on average one year from purchase. During this time, the adhesive joint is subjected to a range of chemical and environmental conditions, depending on the nature of the shoe (Rama Iyer, 1968). The joint is often subjected to moisture, both from the environment, and perspiration from the wearer. Despite this, the joint generally performs well in service, with relatively few failures. Selection of adhesives quality is very important parameter in footwear production, adhesive viscosity ,Solid content (15-20% Minimum level) tacking effect, green bonding, peel strength properties is very important, Temperature activation, curing times is very important for adhesives bonding purposes. Incase poor viscosity and tacking effect is not optimum level this adhesive is not suitable for out sole attaching in footweras (Jose Miguel Martin, 2004). After that inline process also leads to bonding failure such as upper bottom skiving, Hand lasting allowances and seaming temperature 90-100 Degree (8-10 seconds) must for lasting process, outsole marking, upper buffing, outsole buffing width 10mm minimum, Adhesive applying standard methods, Hot oven machines temperature 60-65 Degree for water based cement and primers and environment humidity, out sole attaching methods, out sole pressing machines operation (35-45 kg load and 12-15 seconds minimum for Rubbersole) and chilling (cooling machines) operation also effect the bonding strength in footwear manufacturing. In this review articles mainly focused the inline up normal process and quality standard techniques to control the outsole bonding failures. Nowadays lot of outsole mater.

So each outsole attaching Footwear Company used so much of branded water based and solvent based adhesives. Attaching strength is very important quality for customer and consumers. Poor attaching footwear market is big challenge, thus the types of footwear manufacturing company meet lot of financial loss due to this poor adhesive usage. In this article refer the special attention and importance of bonding strength for finished products. All footwear company first knows the knowledge about bonding test importance (Mayan *et al*., 1999). Purchase adhesive material having A01certified test (Control and monitoring of hazardous substances) report is must, after that this material is handover to production lines process. Today SATRA has a unique position in the footwear industry with unrivalled experience in footwear research and development and footwear testing. This testing laboratories house the most comprehensive range of footwear tests and footwear test equipment, and applied to footwear components Footwear testing highlights the issues that are important to consumers such as comfort fit, performance, durability and safety. Accurate footwear testing is also important to ensure footwear product meets with legislation wherever it is brought to market. SATRA offers expert guidance through the General Product Safety Directive, national, European and international directives, standards and test methods, as well as developing its own performance guidelines and footwear test methods which are recognized and valued throughout the footwear industry (Petrie, 2007). This review refers the FIFO system (First in and First out) in all adhesive storage, based on the expiry date this material is handover to production control and water baesd adhesive mixing duration Minimum 8-10 Minutes (String RPM 300-500 per Minutes and usages duration 2 Hrs. adhesives materials having MSDS date must and thermometer is must for evaluate the room temperature in storage room, 32 degree centigrade and 47 humidity is optimum for all adhesive storage area. More than three month Adhesive left in store, adhesive bonding strength is improved by primer, water based solvent always white colour and solvent based may be natural colour. Adhesives stirrer process also very important for bonding strength so all footwear store mixing room having weight tools and Digital techno meter for assess the RPM speed of the stirring machines. Footwear industry mainly focus this section bonding failure reason may be easily identified and immediately improve the action planes and standard quality. SATRA universal testing machines is currently used for determine the footwear adhesive sole bonding test and Minimum bonding strength Rubber sole in water based adhesives is large size 3.5 is 3.5N/mm and kid size shoes standard is 2.5N/mm.(N-recorded force, mm=width of the specimen). FGT-13 full shoe sole bond tensile (SATRA) and sometimes customer needs after washing sole bonding test reports this test methods is FGT-14, nowadays some polymers compound is used for footwear decorations, this bonding strength also very important in footwear manufacturing (George SATRA, 2014).

Figure 1. Adhesion bonding failure images (finshised shoes)

Figure 2. Closing process skiving failure images

Figure 3. Assembly line process failure images

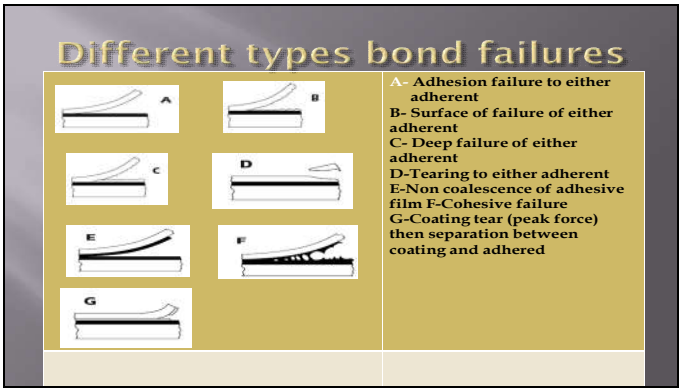

Figure 4. Types of adhesion bonding failure

Normally FGD28 test will evaluate the bonding strength Directed moulded polymer, TPU and silicon are used for decoration parts in footwears, common polymer compounds standard adhesion bonding strength flexing area 2.7N/mm,

non flexing area 2N/mm. Another important adhesion bonding strength is parts pulling test(FGT 08) Tongue and Velcro, lace loop strength also tested in this test methods, Common standard 250N/mm for water based adhesives and tensile test machine speed is 100(mm/minutes). This review article clarify the above bonding failure problems and give some data to control the above up normal issues in footwear productions. SATRA is acknowledged as the leading authority on most aspects of footwear testing, including durability testing and slip testing and sole bond testing.

Conclusion

Footwear manufacturing unit will focus in each process, it will easily improve the production efficiency and customer fulfillment and company development activities. Particularly in this paper only identify the problems and prevention methods in adhesive bonding failures. This process is main part in whole process, incase this operation is up normal totally finished product loss their appearance and trade values. Today water based adhesives and solvent based adhesives, latex also mainly used for manufacturing process. This adhesive material importance and standard quality parameters and A01 certificate important are clearly mentioned in the above area. Customer and consumers always like durable products so in footwear production also having lot of quality standards and appearances. Bonding failure reason is very important points to production industries (William SATRA, 2009). In this area they are not technically focus totally all bulk production will meet lot critical bonding quality problems. In process line also one of the important parameters for bonding failure reasons, in this review thoroughly identify the inline process up normal operation and give some special suggestion to control the above such types of bonding issues. From upper components lasting margin skiving, hand lasting, marking, lasted upper skiving, out sole buffing standards, adhesive application quality methods hot oven temperature, attaching standards and attackers skilled requirements, outsole pressing machines quality standards, chilling times and their importance are clearly mentioned in the articles. This techniques is very useful for all footwear industries and easily they will collect well knowledge from problems area and action plan also clearly indentified. Material selection and work process importance's are also introduced in this research articles. Footwear product nowadays daily uses for all peoples, so demand is higher than other consumer products (George SATRA, 2014). All ways peoples like good quality standard, appearances of finished products. So footwear company they will take special care about quality and durability, this parameters is satisfied for consumers, above company products easily familiar for commercial trade.

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