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HOT PLATE BUTT WELDING OF THERMOPLASTIC DRIVE BELTS

Industrial development is associated with an increased demand for machines for manufacturing and transport of both semi-finished and finished products. Different types of machines operating in food processing and light industry utilize drive belts and conveyor belts with circular cross-section which are most often made of thermoplastic elastomers. In this article overview of manufacturing technology of this type of belting is presented. Special attention is given to the secondary processing of constituent materials, in particular the technological process of joining. Furthermore, an analysis of material conditions was carried out. The resultant considerations will be used to identify the further steps for studying the joining process and the material in question. The end result is the design of an automatic joining device for timing belts to improve product quality and process efficiency.

Keywords: drive belts, butt welding, thermoplastic elastomers

1. INTRODUCTION

Modern machinery and instrumentation employed in the industry are becoming increasingly more complex which stems from:
- considerable progress in technology,
- the necessity to meet high quality standards for manufactured products,
- ensuring safer working environment,
- meeting the expectations to reduce manufacturing costs by improving reliability and simplifying machine operation procedures.

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These factors affect the growing demand for automated machines by the industrial sector which utilize polymer drive belts with circular cross-section in their drive and conveying systems (Fig. 1).

Fig. 1. Elastomer drive belts with circular cross-section [BEHAbelt 2015]

They are commonly used in drive systems of e.g. rolling mills, roll-feeders, sorting lines as well as in conveying elements of belt feeders [Domek and Malujda 2007]. Their primary purpose is to transmit torque between subsequent roller mechanisms or workstations. Machines utilizing this type of belts are commonly used, especially in light industry (e.g. paper making or food processing), which leads to very high demand. Belting manufacturers supply the machine market, their products being utilized in first installation as well as for spare parts. High demand necessitates that the produced amounts of belting is rapidly increasing, reaching hundred thousands of items. This calls for further automation manufacturing, especially the joining process.

Therefore, it was attempted to design an automated device for butt welding of elastomer timing belts with circular cross-section [Wałęsa 2017]. Its application in industrial practice allows to meet the requirements and needs as described above.

In the design process, the following conditions were taken into consideration:

- properties of the joined material,
- the structure of the manufacturing process of polymer timing belts with circular cross-section,
- usable technology for joining of belts,
- physical aspects of selected joining method,
- possibility to automate the butt-welding method for belts.

The result of analyzing these factors influences the final construction form of the device.

2. PROPERTIES OF WELDED MATERIAL

When designing the machine for welding timing belts, it is important to analyze the constituent material. As per the assumptions, the process of butt welding shall be applied to belts made of thermoplastic polyurethane, a polymer material. It contains various additives such as: organic and non-organic fillers, plasticizers, stabilizers, lubricating and coloring agents. These additives allow modifying the properties of the base plastic material in order to obtain the desired characteristics in relation to its usability, durability, aesthetics and required stability [Ashby and Jones 1996].

Drive belts are made of polyurethane. This peculiar plastic material depending on its chemical composition can be classified exclusively as a thermoplastic material, or may exhibit features that are characteristics for both thermoplastic and elastomer materials. Physical and chemical properties of polyurethane are strongly dependent on its chemical composition, structure and molecular mass [Żuchowska 2000]. The polyurethane used in drive belts and conveyor belts is classified as thermoplastic elastomer. Its structure comprises both amorphous and crystalline regions (Fig. 2).

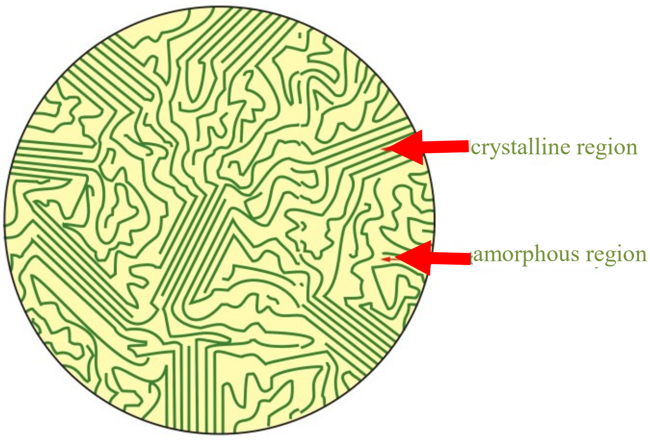


Fig. 2. Example structure of semi-crystalline polymer [Dobrzański 2002]

Consequently, the characteristics of this material combine the properties of both groups. Its strength and resistance to chemical action are similar to crystalline plastics. On the other hand, plastic formability and solubility in some types of solvents results from the presence of amorphous regions in their structure. A characteristic feature of polyurethane is its peculiar (in comparison to other plastics) behavior when exposed to elevated temperatures. The macroscopic symptom of its characteristic phenomena is maintaining properties which are typical for elastomers in temperature up to approximately 100°C, whereas the material becomes softer and exhibits characteristics typical for thermoplastics when heated to higher temperatures [Ciszewski and Radomski 1989].

Polyurethane is usually formed by carrying out addition polymerization of diisocyanites with dialcohols. Depending on manufacturing conditions, it may contain various groups: ester, ether, urethane, carbamide and aromatic rings. For this reason, the hydrocarbon chain features extensive branching which has a significant impact on characteristics which can be modified in a large scope, by means of appropriate chemical reactions [Żuchowska 2000].

Polyurethanes exhibit a segmental structure. The hydrocarbon chain consists of alternating flexible domains: methylene, ester or ether, as well as hard groups: carbamide, urethane or aromatic. The inflexible segments are responsible for the material's high resistance parameter [Puszka 2004]. On the other hand, the flexible segments improve its ability to deform. The domains do not mix, forming a two-phase, heterogeneous structure (Fig. 3).

The physical characteristics and properties of these plastics depend on the percentage ratios of flexible and hard domains. Fully flexible polyurethanes contain 60% to 80% flexible segments. This causes the material to be elastic and easy to deform. On the other hand, the presence of hard segments improves the mechanical strength [Żuchowska 2000].

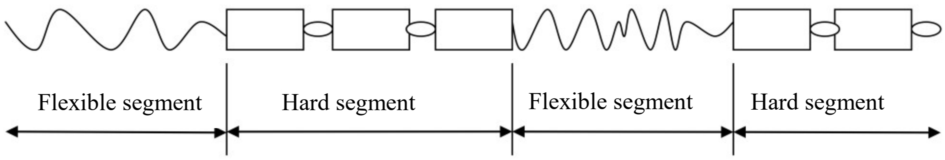


Fig. 3. Example polyurethane structure [Puszka 2004]

During formation, polyurethanes undergo reticulation by sulfur, owing to the presence of unsaturated groups. In temperatures under 100°C, their characteristics are similar to elastomers. This allows to maintain flexibility and deformability. With the increase of temperature, reticulating bonds dissociate which improves plasticity allowing polyurethanes to be hot-welded. The reticulation and dissociation process of bonds is reversible. This allows for thermal processing after which original characteristics are restored [Ciszewski and Radomski 1989].

What follows from the analysis, plastic material under consideration exhibits a number of physical properties that are modifiable and advantageous if employed in manufacturing of drive belts and conveyor belts which makes the materials highly universal. Furthermore, polyurethanes feature relatively high value of elastic modulus, good tensile strength and resistance to repeated bending, which are highly relevant for drive belts and conveyor belts. Their abrasion resistance, tear resistance and vibration suppression parameters exceed other thermoplastic materials. Furthermore, they are characterized by good thermal insulation parameters.

Another relevant factor for the considered application for this material is lack of susceptibility to various chemical agents. This includes oxidizing agents, acid solutions, lubricants, oils and organic solvents. Consequently, the materials may be employed in conveying systems of production lines where the presence of chemical agents can be problematic for other construction materials.

The variety of available polyurethane materials makes it difficult to specify exact numerical data of their characteristics without carrying out detailed testing. Only approximate data are available. The maximum temperature value in which the material maintains its physical state (elastic solid body) is between 80°C to 120°C. One can assume that the tensile strength in room temperature is between 20 MPa to 70 MPa, elongation at break is from 200% to 800 %, and hardness is between 35° and 98° according to scale A using Shore's method of measurement [Madej and Ozimina 2010].

3. DRIVE BELT MANUFACTURING TECHNOLOGY

The manufacturing of drive belts from thermoplastic materials is a multi-stage process. It is important to analyze it to find correlation between the employed means and methods of processing and the final product. Drive belts are manufactured from heat-weldable belts with circular or annular cross-section. They are wound and permanently joined to form a closed shape with specific length, depending on the building specification of the finished product. Belt lengths of several dozen millimeters to several meters are common [BEHAbelt 2015].

3.1. Physical and chemical pre-processing

On the first stage of manufacturing, the plastic materials are processed using physical and chemical pre-processing methods of the second type [Żenkiewicz 2002]. Semi-finished product is obtained from powder or granulate. The processing methods include, among others: injection, extrusion, press molding, vacuum forming, casting or calendering. The form of manufactured semi-finished products depends on their application. Normalized shapes can be achieved (e.g. boards or rods) as well as any forms, entirely dependent on the mold geometry.

Belts are manufactured from flexible tubular or cylindrical rods made of thermoplastic polyurethane material with special characteristics. The manufacturing technology involves continuous extrusion or injection [Sikora 1993]. Semi-finished circular belt diameters are from several to several dozen millimeters and considerable length, as necessitated by the production programming. However, such a solution is far from efficient from the standpoint of storage and transportation. The belt material is flexible and exhibits shape memory together with a minimum allowable bending radius. Consequently, the semi-finished products are machine-wound into spools with length between several dozen to several hundred meters [BEHAbelt 2015].

It was concluded that this stage of manufacturing is not subject to change. It does not affect product manufacturing and storage technology. Hence, further analysis of this manufacturing stage is aimless.

3.2. Secondary physical and chemical processing

The next stage of manufacturing a finished belt is the final processing. The process involves the operation of joining the plastic material which is classified as physical and chemical processing of the first type [Żenkiewicz 2002]. It utilizes selected technologies for joining plastic materials. The resultant belt is ready for installation in the drive or conveyor system of an industrial machine. This stage of manufacturing usually consists of several actions (Fig. 4).

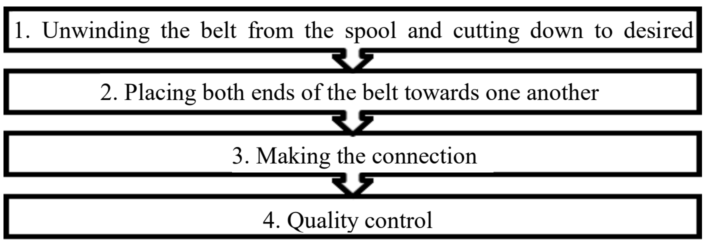
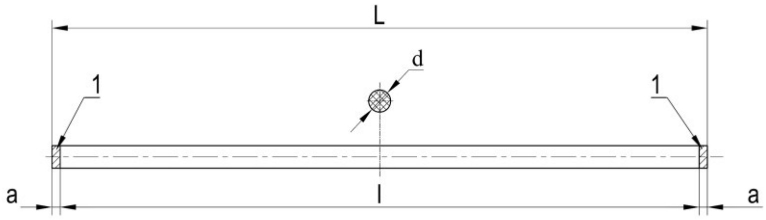


Fig. 4. Timing belt manufacturing flowchart

The first required action is unwinding the belt from the spool and cutting it down to desired length (1). The resultant section of the timing belt constitutes the desired circumference of the manufactured belt with the necessary allowance for material loss in the joining process. After making the above considerations, the active length of the finished product should be equal to its circumference measured in the axis of symmetry of its cross-section (Fig. 5).

When carrying out the cutting operation, it is important that the blade is positioned perpendicular to the axis of symmetry of the lateral cross-section. This allows correct contact between two end surfaces during subsequent processing (2), which involves placing both ends towards one another, under the force *F*. It is important to ensure concentricity of both ends before making the connection (Fig. 6). This is usually achieved by utilizing additional guiding elements.

Belt after cutoff



Belt after joining

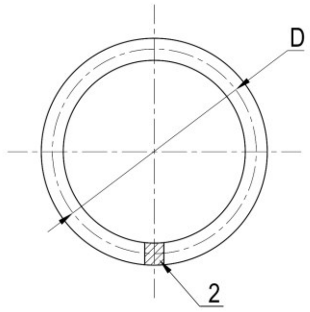


Fig. 5. Dimensional interrelations for belt with circular cross-section, wound to form a circular shape: L – total length of cut belt, l – length of finished belt (circumference after joining), a – allowance for loss during the joining process, d – belt diameter, D – diameter of the circle formed with the cut belt, 1 – allowance for joining, 2 – belt joining area

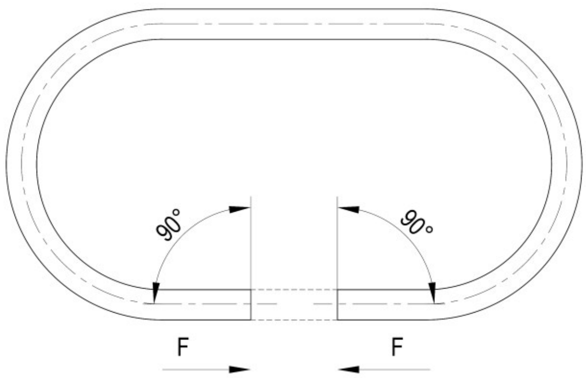


Fig. 6. Belt positioning diagram before proceeding with the joining: F – force required to draw the belt ends together

The belt may be formed into any other closed shape, provided the minimum bending radius is observed. It is usually provided in material data sheets in form of the minimum roller diameter which the material can wrap around.

The next action is to make the connection (pt. 3 on Fig. 4). The parameters for this stage are crucial for the product quality. Belt connection can be carried out via different methods, in particular the ones that are preferred by the manufacturers.

The final stage of the process is commissioning of the finished belt with quality control procedures afterwards. Its scope should involve:

− maintaining correct belt dimensions in the joining area. The diameter of the finished timing belt at the connection must not be different from the average value for the solid material. The thickening of the material may be caused by, e.g. inaccurate removal of flash after heat-welding or by expanding of the belt by the metal connecting element. On the other hand, material contraction may be caused by, e.g.: permanent material deformation, inaccurate connection of end surfaces, or removing too much material with the flash. Such dimensional imperfections are unacceptable for the finished product as such timing belts are usually coupled with belt pulleys manufactured to a great degree of accuracy. Deviation from expected dimensions may cause variation of speed and torque. Consequently, unwanted vibrations may appear to cause additional, excessive stress at the belt cross-section [Domek and Dudziak 2011], which eventually leads to accelerated wear,

− maintaining concentricity of belt ends together with parallel position of end surface areas. Such faults are most often caused by imprecise alignment of both ends of the belt and carrying out the connection in such position. Similarly to dimensional defects in the joint area, such inaccuracies disqualify the product. Lack of concentricity on belt alignment when performing the joint causes vibrations during use which may cause accelerated wear. Manufacturing faults of this type should therefore be eradicated from the process,

− inaccurate joint, e.g. incomplete along the entire cross-section. Such faults can be caused by faulty joining mechanism or if belt ends are improperly aligned. The timing belts exhibiting such faults should be discarded because of high probability of failure to meet the specified strength parameters which means it is highly likely to be prematurely damaged.

This is the final key stage of manufacturing drive belts. Finished and properly manufactured product is packed and handed over to the end-user.

4. POSSIBLE JOINING METHODS OF THERMOPLASTIC CIRCULAR BELTS

4.1. Overview of joining methods

Numerous methods of joining plastic components are available, employing various physical phenomena (Fig. 7).

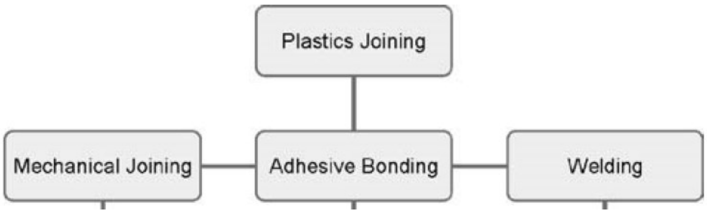


Fig. 7. General overview of different methods of joining plastic materials [Grewell and Benatar 2007]

Considering the process of creating butt joints for drive belts, various possibilities were taken into account including, among others:

− mechanical joining, utilizing connecting elements allowing to join belt ends with annular cross-section. An example of such solutions is the FBN series connector manufactured by BEHAbelt company (Fig. 8).

Fig. 8. FBN series connecting item by BEHAbelt in a drive belt [BEHAbelt 2015]

The utilization of such connecting elements is particularly easy for hollow belts. When joining belts with solid circular cross-section, it is necessary to drill out an orifice along its axis with exactly specified diameter and depth. These connecting elements use conical frustum spigots placed at the end of a cylindrical section together with a cylindrical interlocking collar at the center. Joining belt ends in this method entails forcing the connecting element into the opening at both belt ends, until the belt end surface area presses against the collar. Force of friction between the conical section surrounded by the flexible belt and the material keeps the connecting element inside the drive belt. Additionally, in this particular case, the conical section deforms the internal side of the belt with the sharp edge. This causes the joint to become inseparable in the classic sense. Any attempt to separate the ends causes the sharp edge of the conical section base to irreparably damage the internal surface of the orifice in the belt. This phenomenon is disadvantageous.

Another method of mechanical joining of belts is a sectional joint which allows a degree of bending in the joint area [Wałęsa 2017]. Similarly to the solution described above, it does not allow full flexibility required for use on small diameter rollers.

In analyzing the mechanical methods of joining non-flat driving belts and conveyor belts, one needs to draw attention to the fact that introducing an additional connecting element, usually made of metal alloy, causes a local change to the mechanical characteristics in the joint area, as it becomes inflexible. Such an effect is unacceptable in many situations, as the belt is always coupled with belt pulleys, which often have small diameters. For this reason, it is required that its bending radius is as small as possible. Introducing an additional inflexible component in the orifice inside the belt may cause swelling, leading to localized increase in external diameter, which is undesirable. For these reasons, this joining method is not considered in the planned design.

– adhesive bonding, this method creates a joint by introducing additional adhesive material into the surface to be connected. Adhesive bonding is a commonly used method of joining many different engineering materials, e.g.: metallic materials, ceramics and plastics. In many industries, e.g. aerospace technology or automotive technology, adhesive bonding replaced mechanical joints. This is a consequence of the following factors: attractive strength parameters of the joint, high corrosion resistance of the joint, lower weight and better aesthetic properties. Good ability to transfer mechanical loads, especially in joints susceptible to shear force, results from an even distribution of stress in the joint. Additionally, adhesive bonding does not cause the formation of disadvantageous heat affected zones, as they do not require to subject the joined material to high temperature.

In essence, adhesive bonding requires to introduce adhesive agent between the surfaces of joined materials. The process is facilitated by two kinds of physical phenomena: adhesion and cohesion. The first one is strongly associated with surface wettability, affected by the combination of properties of both the adhesive and joined material, in this case the polyurethane belt. Adhesion is a measure of adherence of the joining agent to the joined material. Stronger adhesion means better bonding between the adhesive agent and the surface. This is a vital factor as good adhesion reduces the probability of damaging the joint at the boundary area between the adhesive and joined material [Jasiulek 2006].

Cohesion, on the other hand, is a measure of connectivity of materials. Its measure provides information on the intermolecular forces inside those materials. Higher cohesion means more connectivity in the material. For adhesive agent, this improves its resistance to mechanical stress, thermal resistance as well as resistance to chemical action. An important factor in adhesive bonding of plastics is the possibility of chemical bonding between the adhesive and the joined surfaces, which is related to the concept of chemisorption. This phenomenon determines the use of proper type of adhesive for every type of plastic material. In the ideal situation, the chemical composition of the adhesive and joined material is similar. In such a case, hydrocarbon chains of adhesive agent and plastic material easily bond during a chemical reaction [Jasiulek 2006].

What follows, adhesive bonding calls for taking into account many different factors which requires performing additional technological operations. Apart from the curing and stabilizing time required in standard adhesive bonding, one also needs to consider: cleaning and degreasing as well as activation of bonded surface. Both activities affect adhesive adherence to the base material. Surface activation facilitates forming of chemical bonds between the adhesive agent and the joined plastic. The activation method is usually via flame or plasma treatment. It entails burning the external, thin layer of polymer in order to destroy long hydrocarbon chains on the material's surface. This forms free functional groups which easily react with the adhesive [Jasiulek 2006].

All the above considerations mean the adhesive bonding process of polyurethane belts is complex and multi-stage. Furthermore, one needs to observe that it introduces an additional, foreign material, usually with different characteristics from the joined plastics which is disadvantageous in this application. This in an important argument against adhesive bonding of belts. Additionally, according to the strength of material theory, adhesive bonds exhibit greatest strength when transferring shear loads up to 150 MPa [Kucharczyk and Żurowski 2005]. Tensile forces, similarly to bending moments, constitute unwanted loads. Considering that drive belts primarily operate under such conditions, it follows that it is not the optimal application for adhesive bonded belts. If this joining method is used, the joint should be redesigned, whereas the most advantageous solution would be to use a lap weld joint. Unfortunately, the area of such joint may exhibit different mechanical characteristics from the rest of the solid belt which causes improper operation of the mechanical system employing such a component. For this reason, it was decided against using the adhesive bonding method for belts.

− welded connections are available in many different variants (Fig. 9). These are an alternative to the above mentioned solutions. Taking into account the specific properties of the joined material, which is a thermoplastic polymer, they are relatively easy to employ.

Hot gas welding usually calls for introducing additional binging material into the joint area which alters the physical properties of welded materials at that location. Additionally, such processing causes problems with outflows of melted material from the joint area regardless of the binding materials used, this usually causes product faults. Accounting for the geometry of the joined item, it is also difficult to carry out, technology wise. For this reason, this method shall not be considered further.

Induction welding entails introducing the joined material into the electromagnetic field of two solenoids. Their reciprocal electromagnetic interaction creates eddy currents in the heated materials, increasing its temperature to the value required for welding [Jasiulek 2006]. Induction welding requires costly equipment, therefore it is rarely used for joining drive belts. This method was rejected based on the difficulty in application and controlling the process.

Resistance welding entails introducing a weld nugget in the joined area. This is disadvantageous from the standpoint of the discussed application, as the wire from the nugget is left in the heated material after the weld is made [Klimpel 2000], which excludes its use for joining drive belts for drive systems and conveyor systems.

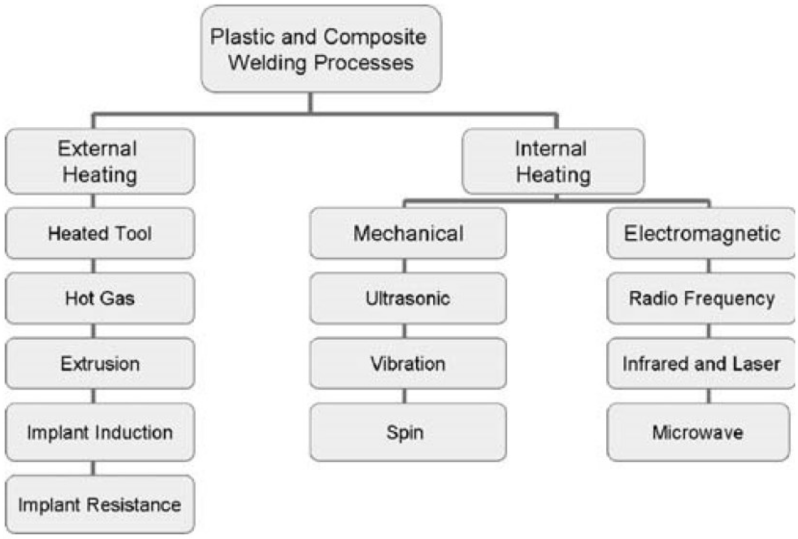


Fig. 9. Types of welded connections for plastics [Grewell and Benatar 2007]

Electromagnetic, laser, microwave and ultrasound welding was preliminary rejected. This stems from comparatively high cost of carrying out such technological processes. An additional factor limiting the application of these methods in industrial practice is the complicated process control procedure. These methods are usually employed in laboratory testing or for single unit manufacturing which calls for exceptional degree of accuracy [Grewell and Benatar 2007].

Other welding methods, e.g. hot plate and friction welding (both vibration and spin method) appear relevant from the standpoint of belt joining. Consequently, a more detailed analysis was carried out for these processes.

4.2. Fusion welding methods

Fusion welding as a method of joining thermoplastic materials entails heating the items at connection point in order to partially melt and increase plasticity of the material. The next action is to press the joined items against one another. In contrast to welding, no additional binding material is introduced, the joined items are pressed together.

The first method which can be applied to joining timing belts is friction spin welding. It entails setting one of the welded items in rotary motion (in the current application, one end of the belt), and at the same time pressing it towards the immobile piece with pressing force F_t (Fig. 10). The kinematics employed in the process causes pivoting friction at the contact point of the two surfaces. An accompanying factor is very intense heat generation between the welded ends of the belt. The generated heat energy causes partial melting and plasticization of joined surfaces which is the essential factor in friction welding. This state continues until the required partial melting is achieved and the two surfaces can be dependably joined. Afterwards, the rotary motion stops and both pieces are joined with heading pressure force F_s with the same direction as pressing force during friction, but of lower value [Klimpel 2000].

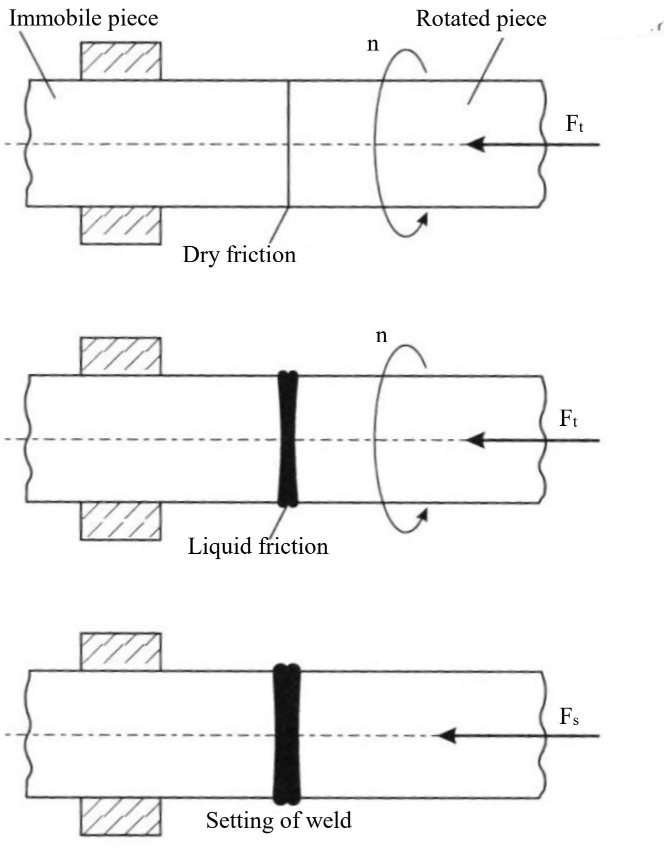


Fig. 10. Friction spin welding process diagram [Klimpel 2000]:
n – rotational speed of revolving piece, F_t – force of pressure during friction,
F_s – force of pressure during heading

Resulting from partial melting of the surface and continuous application of pressing force, the polymer chains in both surfaces are activated, causing them to entwine and join. After a specific amount of time has passed, the pressing force is removed and the congealed area of the joint gains properties of the solid material. The last necessary action is to remove the flash, that is excess partially melted material which was autogenously removed from the joint area.

The phenomena occurring in the course of this process of joining are very complex. The primary variable is the coefficient of friction, as dry friction changes to mixed and fluid friction after partial melting of the surface. Consequently, the description of heat generation phenomenon is complex. Additional issue stems from uneven heating of joined items resulting from inconsistent distribution of speed along the radius of belt ends rubbing against one another. This commonly causes excessive melting of material at the external surface, whereas the area close to axis of rotation is not sufficiently heated.

Friction spin butt welding method is employed when joining plastic products with an axis of symmetry. Its major advantage is simplicity and time required to perform. The process usually requires several to several dozen seconds [Klimpel 2000]. From the standpoint of joining drive belts, the major obstacle may be the introduction of the required welding kinematics. It is not possible to achieve rotating motion of one end of the belt without twisting it. Such a condition is undesirable as it introduces additional stress in the material structure. Consequently, this method cannot be applied for joining belts.

Another variant of friction welding is vibration welding, this method also employs the heat generated in friction between two joined items. In this variant, instead of rotating motion of one piece, a linear vibrating motion of one or both items is employed together with pressing the two items together. The key parameters for vibration welding are: vibration frequency, amplitude, pressing force and duration. These parameters are closely dependant on the type of joined materials as well as the dimensions of joined items. The physical aspects of this process are identical to friction spin welding.

This method of joining is sometimes used for making hot-weld connections for belts. The process is carried out by a manual welding device with two jaws clamping the ends of the belt. One end is immobile, the other performs the working motion. Both jaws are afterwards pressed towards one another via a spring clamping mechanism [Wałęsa 2017].

The other considered method of joining is plate welding with the material being heated by a hot plate. Essentially, the process entails heating both pieces by providing thermal energy to welded surfaces with a heating component, i.e. the hot plate (Fig. 11). The component is electrically heated by heating coil. Consequently, this method may be classified as electrical hot-welding.

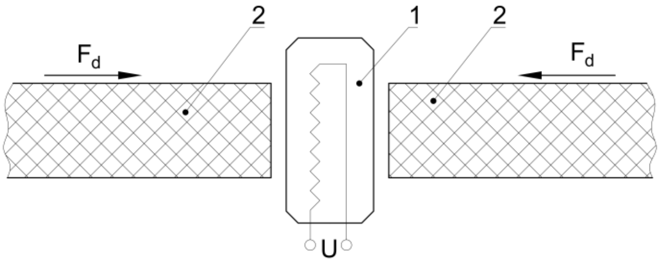


Fig. 11. Belt butt welding process diagram: 1 – hot plate, 2 – joined items; parameters: U – heater supply voltage, F_d – pressure force

When electrical current with specific voltage *U* and intensity is connected to the coil, a specific thermal input is generated. Owing to the phenomenon of thermal conductivity, it heats the entire plate to an exact temperature value. Simultaneous application of the heated plate to both ends of the joined material with pressure force F_d causes an increase of temperature due to thermal conductivity on contact. This causes partial melting and plasticization of the joined material at contact area.

In the case of hot plate butt welding, the key process parameters are: hot plate temperature, processing times of specific actions and pressing force of joined items. These parameters, in the case of manual welding, are controlled by the operator. When designing an automatic welding device, it is crucial to select the appropriate parameter values in order to obtain a proper joint.

Comparing vibration welding and hot plate welding, we are able to draw the following conclusions [Krishnan and Benatar 2004, Patham and Foss 2011]:

- hot plate welding is characterized by a longer time necessary to perform the joint, therefore process efficiency is lower,
- hot plate welding is characterized by lower temperature gradient when heating and cooling the joined material. These processes are slower and take place over a longer time. For this reason, the material welded with hot plate exhibits a broader area of heat outflow, which is disadvantageous as the area in which the material characteristics are changed compared to base material is larger,
- during hot plate welding, lower residual stress values after heating are observed which stems from lower speed of cooling of the joint. This is advantageous as residual stress limits the actual joint strength,
- hot plate welding is more advantageous compared to vibration welding for joining materials with low rigidity, including e.g. thermoplastic elastomers. This is caused by the fact that this type of plastics is subject to comparatively large deformation in the course of forced motion during vibration welding; therefore, the required parameters like e.g. amplitude or frequency are not maintained. This has a negative effect on joint quality,
- butt welding, in comparison to vibration welding, does not require as much accuracy in preparing the contact surfaces of the joined items. In this case, the

alignment phase with preliminary partial melting of the material removes the dimensional inaccuracies caused by e.g. faulty cutting,

- the butt welding process is characterized by a lower number of variable parameters which are easier to control. Even if the process is carried out by inexperienced employees, it is easy to set the right time, pressure or temperature parameters. In the case of vibration welding, the setting of amplitude, frequency together with clamping pressure and time calls for a much more experienced supervisor over the welding process.

Considering the above mentioned factors, it was decided in favor of employing the hot plate butt welding method. Industrial practice shows that the technology is easy to employ and therefore much more common.

5. CONCLUSIONS

Analyzing the accompanying factors for the manufacturing process of timing belts with circular cross-section, made of thermoplastic elastomers is very important for designing the device to be used in the joining process. Characteristics of the material together with the course of the manufacturing process affect the choice of optimum joining technology to a significant degree. This allows to design a device adapted to make belt connections utilizing the hot plate butt welding method [Wałęsa 2017].

The next step in designing the machine for automated welding of drive belts is the detailed analysis of the hot plate butt welding process. It should account for the key parameters and their influence on the quality of obtained joints. The resulting conclusions will allow to identify subsequent stages of research with view of achieving comprehensive understanding of the issue of thermoplastic elastomer belt welding. Further study is called for due to insufficient information available regarding hot plate welding of elastic materials. The result of this study will be the design of an automated machine for joining drive belts and establishing parameter setting vales to obtain joints meeting the specification requirements.

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ZGRZEWANIE DOCZOŁOWE TERMOPLASTYCZNYCH PASÓW CIĘGNOWYCH METODĄ GORĄCEJ PŁYTY

Rozwój przemysłu wiąże się ze wzrostem zapotrzebowania na maszyny do produkcji oraz transportu zarówno półfabrykatów, jak i gotowych produktów. Różne rodzaje urządzeń pracujących w przemyśle lekkim i spożywczym wykorzystują w swoich mechanizmach elastyczne pasy napędowe i transportowe o przekroju kołowym. Najczęściej wykonuje się je z termoplastycznych tworzyw elastomerowych. W artykule przedstawiono przegląd technologii produkcji takich pasów. Zwrócono szczególną uwagę na proces wtórnego przetwórstwa materiałów, z których są wykonane, a w szczególności na operację technologiczną łączenia. Dokonano również analizy uwarunkowań materiałowych. Poczynione rozważania będą wykorzystane do określenia niezbędnych etapów badań nad procesem łączenia oraz rozważanym materiałem. Końcowym efektem będzie konstrukcja urządzenia do zautomatyzowanego łączenia pasów cięgnowych, które umożliwi poprawę jakości oraz efektywności ich produkcji.

Słowa kluczowe: pasy cięgnowe, zgrzewanie doczołowe, elastomery termoplastyczne