Detachable Connection for Thin Homogeneous Conveyor Belts in the Food Industry

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ABSTRACT Belt conveyor systems play an important role in many areas of industrial production. Thereby, the transport of foods demands special requirements and restrictions to avoid contamination and microbial growth. The belts used here are often manufactured as yard goods for technical production reasons. After cutting these belts to length, it is necessary to join the ends together. To guarantee assembly, the belts are among other things equipped with detachable connections. Accordingly, this article deals with the development of new detachable connection for thin unreinforced conveyor belts in the food industry. Besides reduction of critical areas (undercuts, breakthroughs ...) which favor the accumulation of bacteria additional focuses are the increase of tensile strength as well as a simple and fast assembly and disassembly of the belt to ensure cleaning and disinfection. Moreover, effective and economic production technologies should be applied.

KEYWORDS belt, joining, food industry

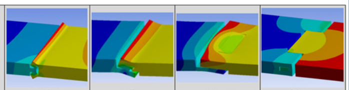
KURZFASSUNG *Lösbare Verbindung für dünne homogene Förderbänder in der Lebensmittelindustrie:* Bandförderer spielen in vielen Industriebereichen eine wichtige Rolle. Der Transport von Lebensmitteln stellt dabei aufgrund von Verschmutzung und Mikrobenbildung besondere Anforderungen und Restriktionen an das Fördersystem. Hier verwendete lebensmittelkonforme Bänder werden aus fertigungstechnischen Gründen oft als Meterware produziert, im Anschluss auf Länge geschnitten und die Enden verbunden. Um die Montage zu gewährleisten kommen dazu unter anderem lösbare Bandverbindungen zum Einsatz. Der Beitrag befasst sich entsprechend mit der Entwicklung einer neuen lösbaren Verbindung für dünne, unverstärkte Förderbänder in der Lebensmittelindustrie. Neben der Reduzierung von kritischen Bereichen wie Hinterschnitten und Durchbrüchen liegen weitere Augenmerke auf der Erhöhung der Zugfestigkeit, sowie einer einfachen und schnellen Montage bzw. Demontage der Verbindung zu Reinigungszwecken. Zudem soll eine wirtschaftliche Fertigung gewährleistet werden.

SCHLAGWÖRTER Gurt, Verbindung, Lebensmittelindustrie

Detachable connection for thin homogeneous conveyor belts in the food industry

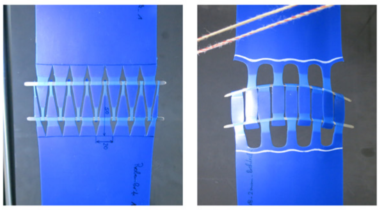
Belt conveyor in the food industry

FEM simulation of belt connections under straight line



	anchor connection	clip connection	stamp connection	hinge connection
maximum deformation	0.45 mm	1.35 mm	1.69 mm	0.51 mm
maximum stress	9.5 MPa	24.1 MPa	73.4 MPa	233.3 MPa (steel insert)

Different variants of detachable belt connections

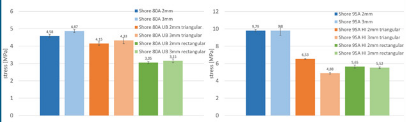


hinge connection - triangular fingers

hinge connection - rectangular fingers

anchor connection - Christmas tree-shape

Comparison of maximum stresses



Motivation

Belt conveyor systems play an important role in many areas of industrial production. Thereby, the transport of foods demands special requirements and restrictions to avoid contamination and microbial growth. The belts used here are often manufactured as yard goods for technical production reasons. After cutting these belts to length, it is necessary to join the ends together. To guarantee assembly, the belts are among other things equipped with detachable connections.

In accordance with the above-mentioned reasons, the objectives of the development can be summarized as followed:

- Development of a new detachable connection for thin unreinforced conveyor belts in for the food industry
- Reduction of critical areas (undercuts, breakthroughs,...) which favor the accumulation of bacteria
- Increase of tensile strength compared to the present state of the art
- Simple and fast assembly and disassembly of the belt to guarantee cleaning and disinfection
- Development/use of more effective and economic production technologies

Design and prototypes

Based on the requirements and objectives of the project four different design concepts: anchor, clip, stamp and hinge connection were developed. By evaluating and assessing these four solutions with regard to deformation behavior, food conformity, fabrication and assembly the anchor and hinge connection were defined as preferred solution. Following steps include FEM simulations of the preferred concepts whereby especially geometrical parameters e.g. size, number as well as constructive execution of fingers, pins and anchors were varied. On basis of these investigations, different prototypes for instance with triangular and rectangular fingers or a Christmas tree-shaped anchor were produced.

Mechanical properties of the belt connections

All prototypes manufactured were examined by tensile tests with an elongation of 100 %. It is quite evident that prototypes with triangular fingers achieve higher stress values than joinings with rectangular fingers. Moreover, belt connections with higher Shore hardness (80A) show significantly worse values than belt joinings with a lower hardness (Shore 95A).

Besides tensile testing of the connections also investigations on the permanent substance-to-substance bond between the joining and the belt ends toke place. However, in comparison to the base belt material the butt-welded belts examined show no relevant differences in strength.

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1. Introduction

In intralogistics continuous conveyors are often used to transport bulk or piece goods between processing stations or transition points. In addition to transport these also perform additional functions like mixing or drying. The diversity and range make continuous conveyors indispensable in nearly all industrial sectors. A belt conveyor is a special type of a continuous convey-or. These transport systems include continuous moving belts running over driving drums and deflection drums with a tensioning device.

Conveyor belts are used in many industrial branches including the food industry. These food belts are primary made from polyvinyl chloride (PVC) and polyurethane (PU). To increase tensile strength belts are often reinforced with textile fabrics like polyester weave. Further-more, the outer layers of the belt can be adjusted depending on the transport task. For example silicone or PTFE can reduce the adhesion between the belt and the transported good. Also polyester fabrics used as a sliding layer decreases friction against the sliding rails of the frame.

The production of conveyor belts with small center distances is mainly implemented by winding or casting. However, longer center distances make it necessary to produce belts as yard goods that are cut to length and joined together. The connection can be executed detachable or non-detachable. Non-detachable connections are firmly bonded by welding or gluing. In contrast to that, detachable joining are positively form locked. Examples for this are among other things strap hook joint, butt strap joint, alligator joint or the zip connection.

Figure 1: conveyor belt system [1]

2. Motivation and Objectives

In the food industry PU belts without textile fabrics are often used to reduce the risk of contamination and microbial growth. These kinds of belts have to correspond to the HACCP-Concept. In many cases, the conveyor belts are not welded endlessly but joined via a detachable connection. Firstly, this has the advantage of a simplified installation of the belt into the conveyor system. Furthermore, it opens up the possibility of an optimal cleaning outside of the conveyor. Currently detachable belt connections made of metal and plastic are already applied. Due to their design, these joining are very susceptible to deposits during production.

High requirements for example avoidance of bacteria formation strongly restrict the choice of belts in the food industry. Besides food-safe materials, also the design of the detachable connection has a key role. Rough surfaces or undercuts for instance favor microbial growth.

Another disadvantage of detachable belt connections are significant lower strengths that usually amount maximum 50 % of the belt strength. In addition, joining areas often show much higher stiffnesses because of additional elements. This leads to malfunctions as well as higher loads which causes a shortened life span.

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3. Belt Connection Variants

3.1. Solutions Concepts

Based on the requirements and objectives of the project four different design concepts were developed. Figures 2 and 3 show a schematic representation of these connections.

The first joining variant is so-called anchor connection. The joining element has the form of an anchor, which is shaped over the entire belt width. The other end has a corresponding negative and creates a form-locking connection. Both parts are predestined for extrusion.

The clip connection (see Figure 2, right) relies on the anchor connection whereby the joining element is rotated 90 degrees.

Another concept is the stamp connection. Here one end has a stamp-shaped form that can be joined to corresponding negative cavity on the other end. Both parts are fabricated by casting.

Design of the hinge connection (see Figure 3, right) generally corresponds to detachable joining that were already established on the market. It consists of two finger-shaped ends as well as a pin out of plastic or steel that links them together. In contrast to existing solutions, the connection is made out of belt basic material. This prevents thickening as well as stiffening of the connection area. Also the bacteria growth is avoided by the reduction of undercuts and pits.

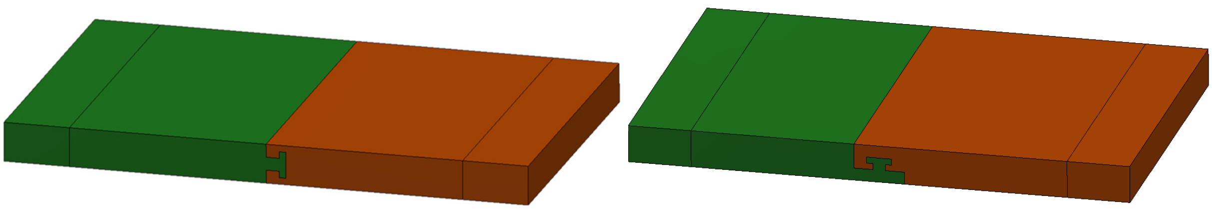


Figure 2: anchor (left) and clip connection (right)

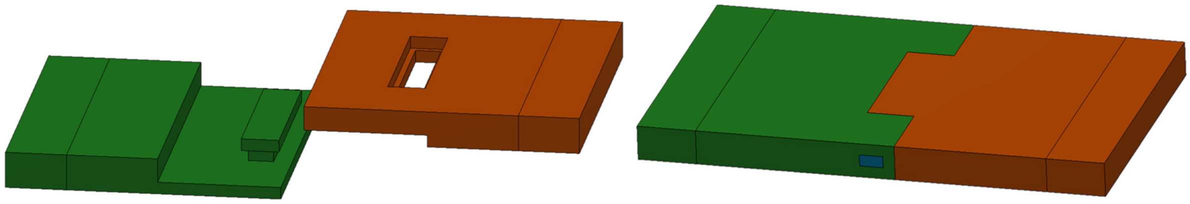


Figure 3: stamp (left) and hinge connection (right)

3.2. Evaluate Connection Variants

The main factor in assessing the four connection variants is deformation behavior. Low stiffness might lead to an opening of the joining, which causes cavities or gaps. Comprehensive FEM analyses, including straight line as well as belt running over a deflection pulley, were made. The results of the simulation for straight line are shown in Table 1. To ensure comparability the connections were designed with the same material cross-sections and without curves. A geometry optimization follows at a later stage.

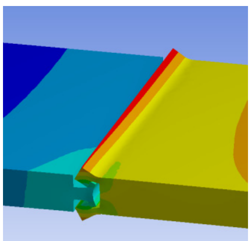
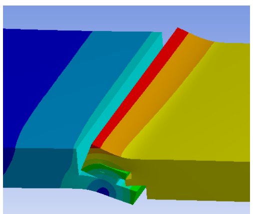
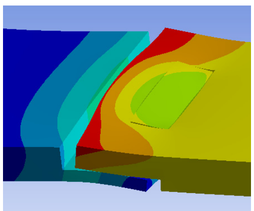
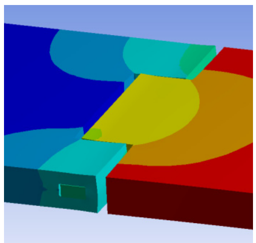
The FEM results show that clip and stamp connection have significantly higher deformation values than anchor and hinge connection. This behavior is a result of the non-symmetrical design, which leads to asymmetrical displacement.

After that, the four connection variants were evaluated and assessed with regard to deformation behavior, food conformity (undercuts, breakthroughs ...), fabrication and assembly. Based on this evaluation anchor and hinge connection were defined as preferred solution.

The following step includes further FEM simulations of the preferred concepts whereby especially geometrical parameters e.g. size, number as well as constructive execution of fingers, pins and anchors were varied. Thus, it was possible to detect dependencies on the deformation behavior and to optimize the design of the joining towards a minimization of deformation.

Until now, different prototypes of the anchor and hinge connection with two different belt thicknesses (2 mm, 3 mm) were manufactured (see Figure 4 and 5). On the one hand these samples have a triangular finger shape with 14 fingers. On the other hand a rectangular finger form with 9 fingers was produced. Furthermore, two ribbed stainless steel pins fix the connection.

Table 1: comparison of deformation behavior based on straight line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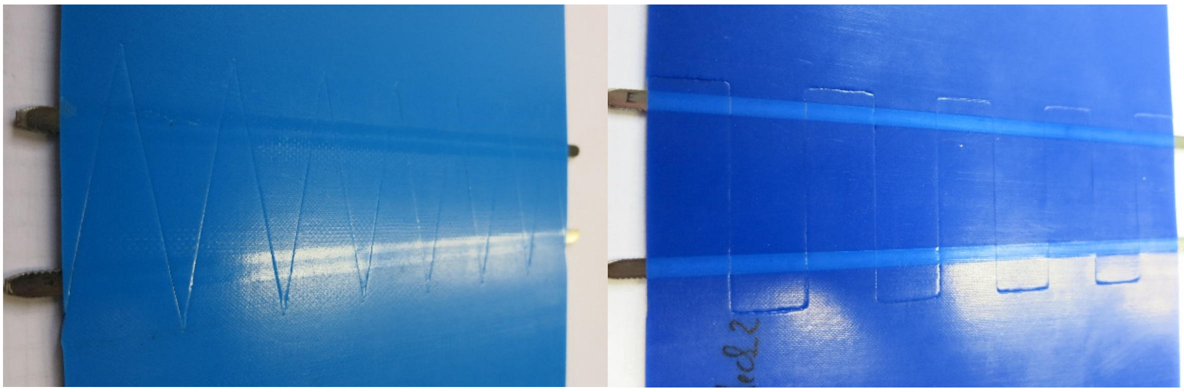

Figure 4: variants of hinge connection: triangle (left), rectangle (right)

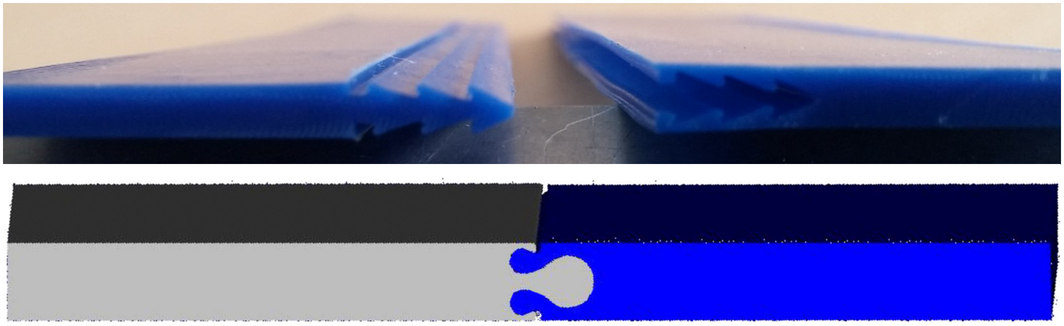

Figure 5: variants of anchor connection: triple anchor (above), puzzle (below)

The first prototypes of the anchor connection were inspired by Christmas tree-shaped anchor (see Figure 5, above). However, bending attempts already showed unfitness of the joining. Even under low forces, the connection failed. After that, a redesign of the anchor towards a puzzle-shape was implemented.

The development of a detachable belt connection also requires efficient manufacturing strategies. This includes an easy but most importantly an economic production for different belt widths up to 700 mm.

The production of hinge connection takes place by filling a mold with thermoplastic polyurethane. Thereby two stainless steel pins are already positioned. After the material is cured steel pins are removed. This procedure makes it possible to create breakthroughs over the whole belt width. In the next step, the fingers were cut into desired shape resulting two connection endings which can be welded on belt. To link belt ends the pins have to be inserted in the breakthroughs.

In contrast to hinge connection, the production of the anchor connection by extrusion would be suited. However in the first place current efforts of manufacturing prototypes deal with casting in a variable mold. This method is currently a cost-efficient alternative to a much more expensive extrusion die. With regard to later serial production the fabrication by extrusion is to be favored.

4. Mechanical Properties of Detachable Belt Connections

As mentioned above, detachable belt connections available on the market are mostly de-signed for belts with textile reinforcement. These joining systems achieve strengths, which have only around one-third of base belt strength. Therefore, a minimum tensile strength of 50 % towards the belt tensile strength is planned. Over the course of the project it has been shown that existing belt materials like TPU (elongation at break up to 800 %) were indestructible by present mechanical testing machines. For this reason, it is not possible to apply breaking strength as evaluation criteria for the connection variants. Instead, stiffness was used as a standard of comparison. However for hinge connection a required permitted tensile force of 3 kg/cm could be reached.

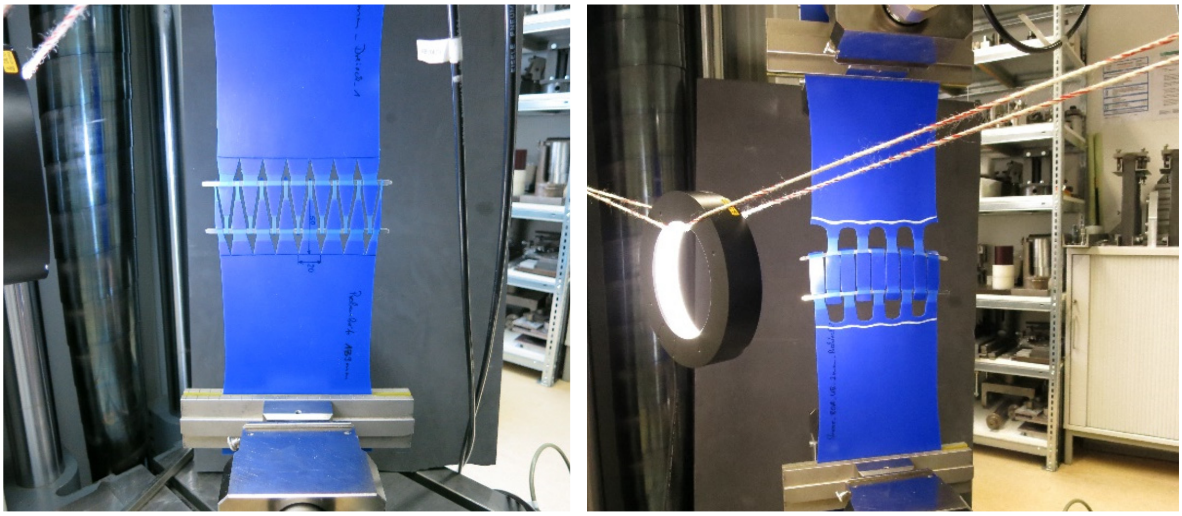

Figure 6: hinge connection during tensile test: triangle (left), rectangle (right)

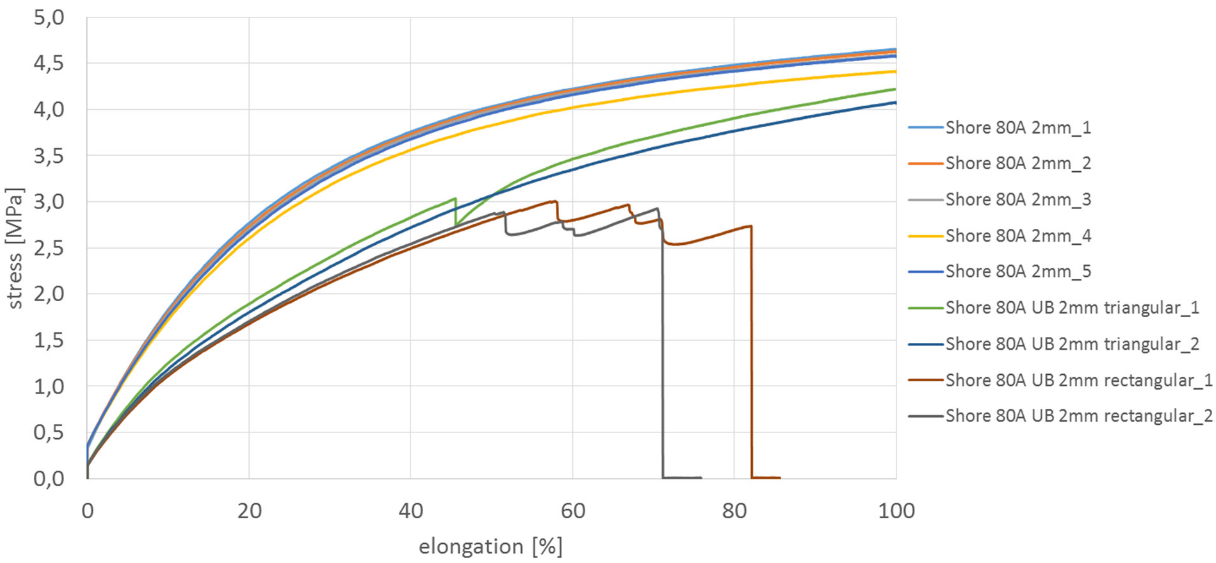

Figure 7: stress strain behavior of hinge connections and base material, Shore 80A

All prototypes manufactured were examined by tensile tests with an elongation of 100 %. Figure 6 shows the deformation behavior of the triangular and rectangular hinge joining. In addition, Figure 7 exemplary illustrates stress-strain distribution of all hinge connections with a belt thickness of 2 mm as well as a Shore hardness of 80A in comparison with a base material belt. It is quite evident that prototypes with triangular fingers achieve significantly higher stress values than joining with rectangular fingers. In this case, belt connections with triangular fingers reach nearly the same forces like the base materials. In contrast, connections with rectangular fingers show an abrupt drop of forces already at about 60 % elongation. This behavior is due to the outer fingers slide from the pin.

In Figure 8 and Figure 9, all mechanical test results of the hinge connection can be seen. As already mentioned, belt connections with lower Shore hardness (80A) and triangular fingers have only slight differences to the base material.

An entirely different picture is taking shape at all prototypes made of thermoplastic polyurethane with higher hardness (Shore 95A). In comparison to the base material substantially worse values can be observed here. Nevertheless, at 100 % elongation tensile stress achieve about 50 % compared to the base material.

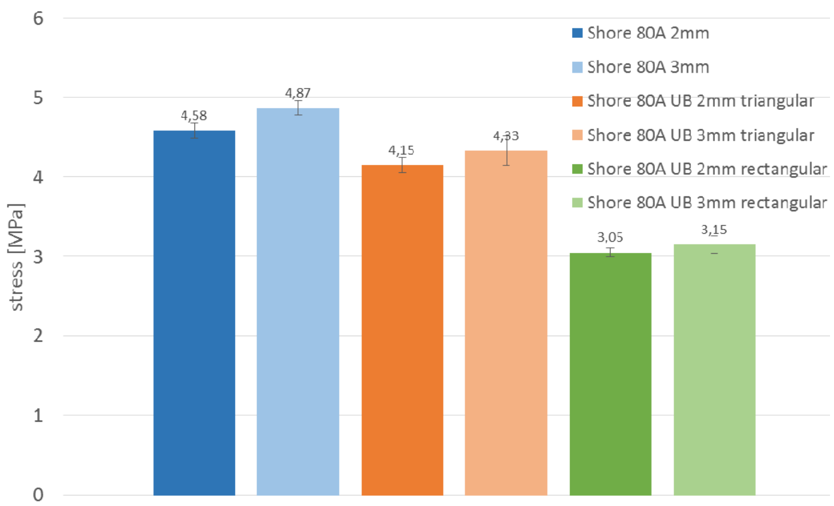

Figure 8: comparison of maximum stress, TPU Shore 80A

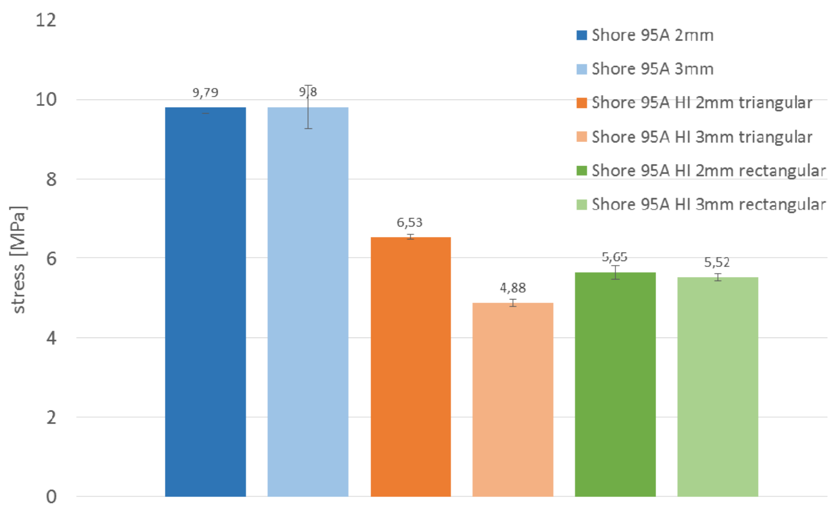

Figure 9: comparison of maximum stress, TPU Shore 95A

Another important aspect is a permanent substance-to-substance bond of the detachable connection and the belt ends. For this purpose belt ends from the same material (TPU Shore 80A and 95A) were butt-welded together and examined by tensile testing. Figure 10 shows the results by means of stress at an elongation of 100 %. It is obvious that there is no reason to fear loss of strength between base material and butt-welded samples.

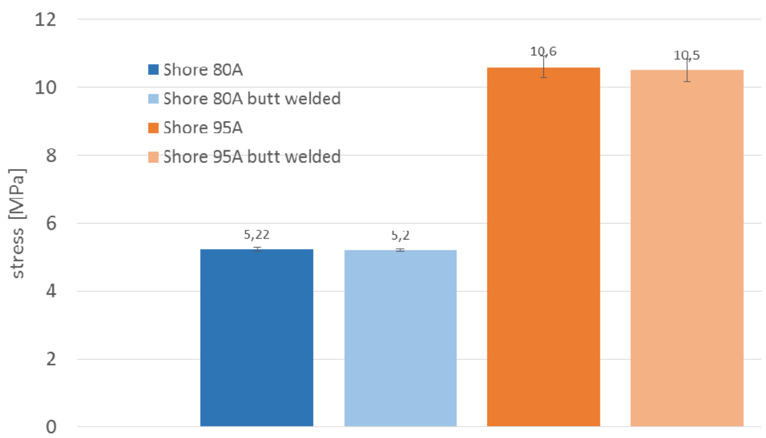

Figure 10: comparison between base material and butt-welding

5. Conclusion and Outlook

The transportation of foods with continuous conveying systems between processing stations provides high demands on conveying belts. For simplified installation or optimal cleaning, fabric strengthened belts are often equipped with detachable connections. Known problems are thickening and stiffening effects in the area of connection. Moreover, these joining are not primarily aimed to food belts. Due to that a detachable connection for unreinforced food belts under the point of view of food suitability and microbial growth should be developed.

Therefore, at first different detachable belt joining concepts were developed. By evaluating these variants with regard to deformation, food conformity, fabrication and assembly two solution concepts were selected. After an optimization of the geometries with the aim of minimizing the deformation, different prototypes were produced and tested. Although the development of a detachable connection for thin homogeneous conveyor belts in the food industry is not yet finished but the function of the linking system could be verified.

In the proceeding of the research project deformation behavior of the connections under real operating conditions has to be examined in long-term tests. Further, functional tests of assembling and disassembling process must be carried out to guarantee permanent use of the joining.

References

[1] Internet presentation, Samro AG: http://samro-ch.site-preview.net/htm/foedertechnik.htm. Visited: March 2017.