Cracking in the Modular Belt for Spiral Conveyors in real operation

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Abstract. This work deals with an investigation of recurrent cracking of the spiral modular conveyor belt over an extended period. The modular belt has been in operation for at least 2 years and is now showing wear that must be solved immediately due to a possible crash of the entire line and stopping of operations. The target of this work is looked for possible causes cracking of modular belt in operation and following solution. The causes included both the wrong setting of the entire spiral conveyor as well as the wrong choice of belt material or internal defects of the belt.

Keywords: Modular Belt, Spiral Conveyor, Cracking.

1 Introduction

1.1 Spiral conveyor

Spiral conveyor (Fig. 1) is a special type of belt conveyor that is mainly used in the food industry. The biggest advantage of this type of conveyor is the use of long times that the products can spend on the conveyor belt, with relatively small installation dimensions. The design enables the using spiral conveyor in various working condition, which are encountered mainly in bakery industry.

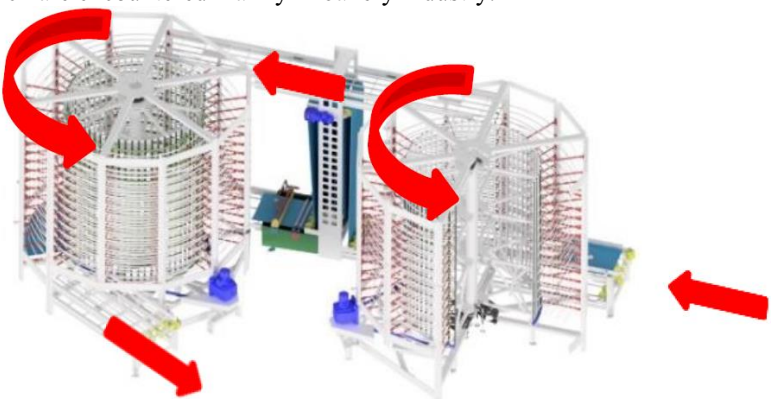

Fig. 1. Two-drums spiral conveyor

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1.2 Modular belt for spiral conveyor

Plastic modular belts consist of modules, often in the form of platelets/links connected by hinge-pins (rods). A “pinless” construction, where the plastic modules are linked without rods, does exist. Modular belts have a toothed underside allowing them to be positively driven by sprockets or a drum motor drive under low tension [1]. The tension in the belt is achieved by its own weight. In mechanical terms, given models of modular belts are subject to a minimum of friction, have high strength, and a high resistance to impact, corrosion and abrasion [2].

For this application is using belt with width 1016 mm, material of belt is from PP and pins from POM which nominal tensile strengths are shown in picture bellow (Fig. 2) [3].

Belt data

Belt material		POM	PP
Rod material		PA	POM
Nominal tensile strength F'_N straight run	N/m *lb/ft*	21000 *1439*	15000 *1028*
Nominal tensile strength F_N in curve (1)	N *lbf*	3200 *720*	2330 *516*
Temperature range	°C *°F*	-40 - 93 *-40 - 200*	5 - 93 *40 - 200*
Belt weight m_B	kg/m² *lb/sqft*	7.5 *1.54*	5.2 *1.07*

(1) For b_n > 610 mm *(24")* higher values are admissible.

Fig. 2. Properties of the M5293 Tight Radius 2" belt [4]

2 Cracking of modular belt

Spiral conveyor had been monitoring for 2 years for collection of data from operation and for testing of several different condition of belt.

Based on the results of study from S. Sanchez-Caballero, it has been possible to determine that the failure of the modular plastic belt is not due to an overload, to the material, or to the manufacturing process, but is in fact due to the poor design of the part. This conclusion will be taken from the mechanical characterization of the material, as well as the strain simulation carried out using FEA and the analysis of the manufacturing process [5].

2.1 Frequent belt cracks

These types of cracks (Fig. 3) in the outermost segments have been occurring for whole observation of spiral conveyor (approximately 40 defective segments).

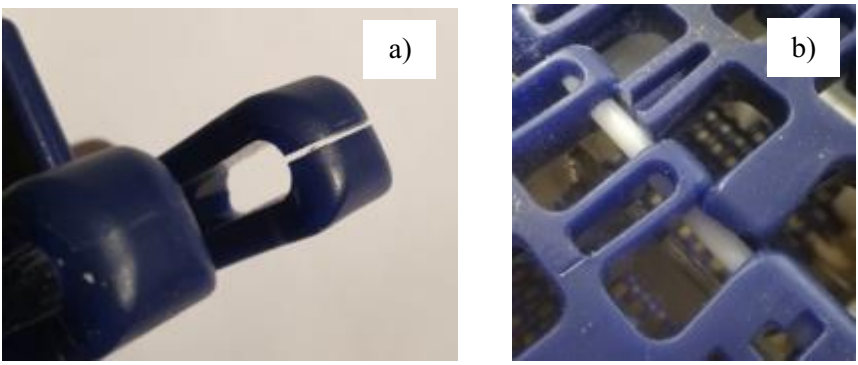

Fig. 3. a) Longitudinal crack of the outermost segment (side view) b) Two cracks in belt segments.

3 Verification of the integrity of the construction of the spiral conveyor

Based on these problems, the integrity of the construction of the spiral conveyor has been verified using several methods.

3.1 Electrical load of the motors

Electrical load of any motors was monitoring for couple months as is mentioned in table 1

Table 1: Current measuring of each motor on spiral conveyor

		Motor 1	Motor 2	Motor 3
February 2020	Current [A]	3,6	3,4	1,2
December 2020	Current [A]	3,4	3,1	1,4
February 2021	Current [A]	3,6	3,3	1,6

As one can see in the table above, the electrical current remains within in the respective limits and do not deviate in any large degree. The only difference is in the limits due to the fact that testing for this safeguard began in February 2020, and the limit needed to be adapted to the load of the spiral.

3.2 Measuring belt load

For measuring belt load was used device of belt supplier for measuring the progressive load on the belt at its outer edge. This device is working with tensiometer, converter and outputs for PC visualization.

Maximum belt load occurs always on the approach to the straight upper section (be-tween B1 – Drum number 1 and B2 – Drum number 2) to the first section of the descending level of drum no. 2.

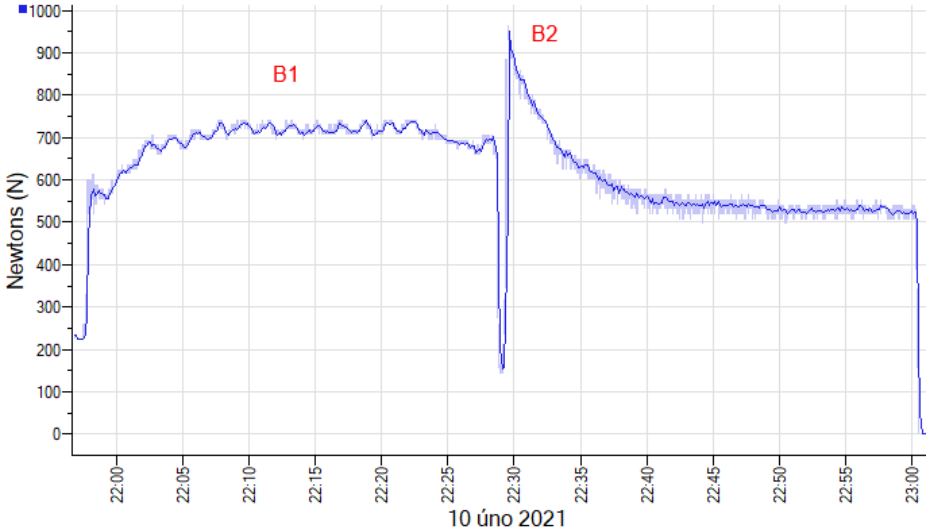

Fig. 4. Progress of the load on the modular conveyor belt

As shown in the resulting graph (Fig. 4), the load maximum values amount to approximately 970 N which is lower in compare with nominal tensile strength in curve (2330N).

4 Tensile and breaking point testing

The testing was conducted using a hydraulic tension testing machine as well as a high-speed camera., both of which were linked to a program that records the results in real time together with test images.

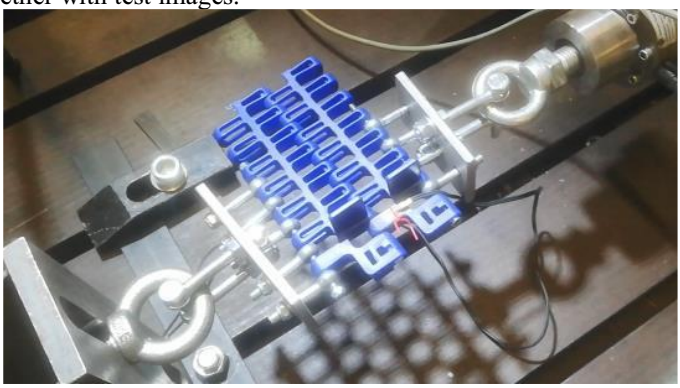

Fig. 5. Setup of a test sample on the tensile testing machine

A sample of the belt is attached via a device simulating a curve in the spiral to the testing machine and is recorded from the top by the camera (Fig.5,6).

Sensors on the testing machine record the growth in force and movement of the hydraulic piston. These values are recorded in the DewesoftX 2020 program.

Tests were made with several samples of belt. New belt, new belt segment, belt after two years in operation and belt segment after two years in operation.

For all result were compared maximum force and type of the cracks.

Movement (mm): blue curve
Force (kN): red curve

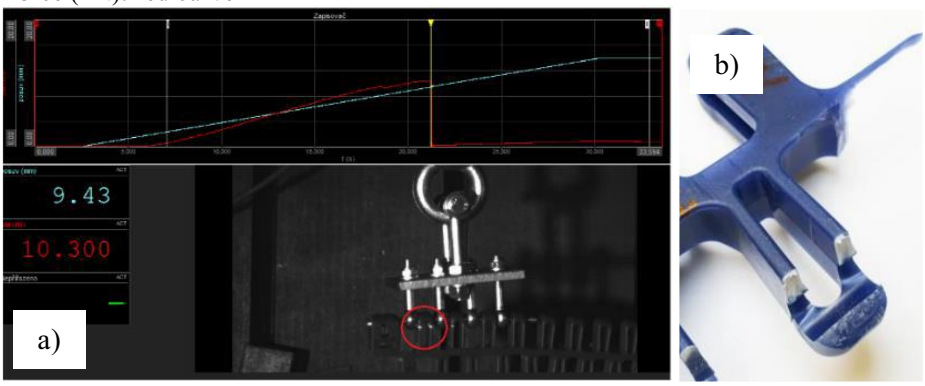

Fig. 6. New belt (1) test a) result, b) crack detail

A detailed view of the segment with the furrow for the pin shows loss of plasticity in the area where the existing cracking issue arises (Fig. 6, 7).

This signifies a weak point, likely a non-homogeneity of materials (to be described in greater detail in the next chapter).

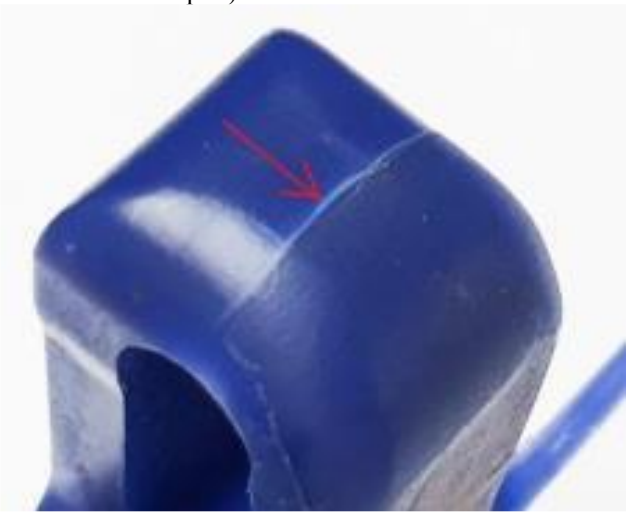

Fig. 7. New belt test (1) – detail

Additional tests were conducted solely on a used belt from operation, which was obtained after two years using.

Sample number 2 (Fig. 8) from the used belt underwent the exact same testing process as the previous belt sample.

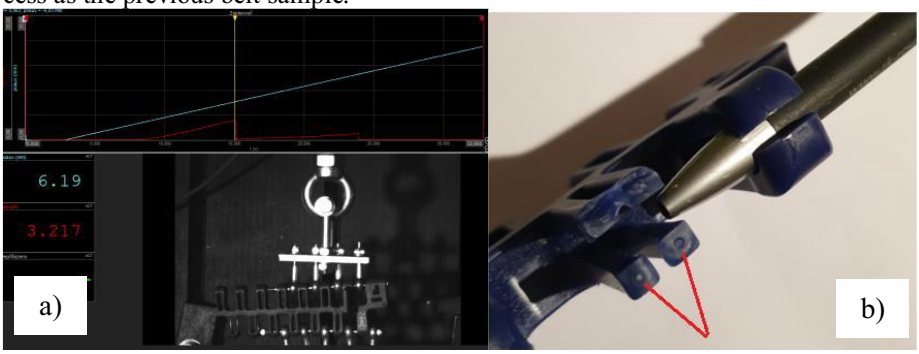

Fig. 8. Used belt from operation (2) test a) result, b) crack detail

A detail view of both cracked modules. We can also see puckering in the second segment of the modular belt, which reduces durability.

In order to obtain more detailed data from the area where the cracking occurs most often, testing focused solely on a single segment of the module.

Sample number 3 (Fig. 9) is also from a new belt. The testing process is the same as in the previous samples.

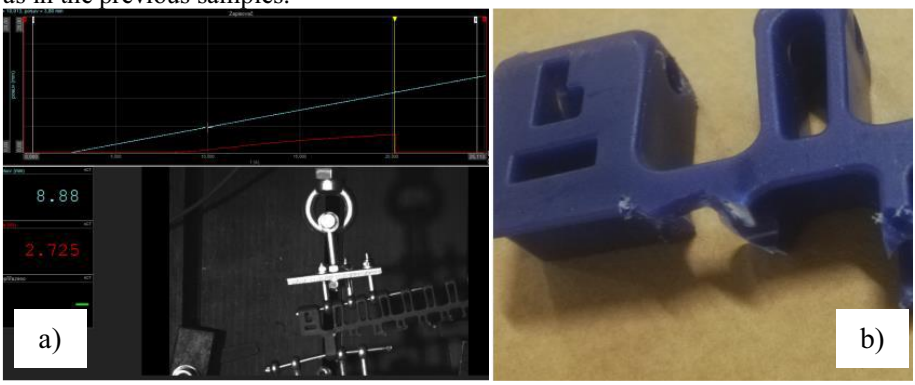

Fig. 9. New belt segment (3) test a) result, b) crack detail

The cracking of the segment occurred on the bottom edge of our tested module, not in the near of the parting line, as it does with the used modules from operation.

The final test using sample number 4 (Fig. 10) is the same as with sample number 2, i.e., a test of the tensile strength of the module opening.

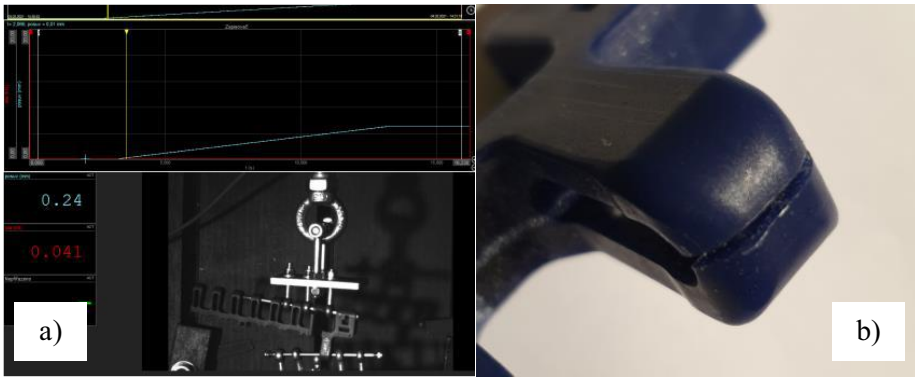

Fig. 10. Used belt segment from operation (4) test a) result, b) crack detail

Table 2: A final comparison of the results of tension and breaking point testing:

Sample No.1 (new belt)	10,3 kN
Sample No.2 (used belt from operation)	3,22 kN
Sample No.3 (new belt segment)	2,73 kN
Sample No.4 (used belt segment from operation)	0,04-0,12 kN

As shown in the test results, the belt that is in operation lost a great deal of its durability.

The next chapters will discuss possible causes of decreased durability.

5 Possible causes of decreased durability

It was arranged a chemical analysis of the modular belt:

- Determination of induction time - oxidation (OIT) - a method for comparing and assessing the oxidation stability of materials at a specified isothermal temperature
- CT / Microscopic analysis

Determination of oxidation induction time (OIT) – evaluation according to ISO 11357-6, measurement and evaluation of both parts [OK part – (1) new belt, NOK part – (2) used belt].

Test device: DSC1/700 Mettler Toledo

Samples were used from previous tests so there could not be confusion or deterioration of samples.

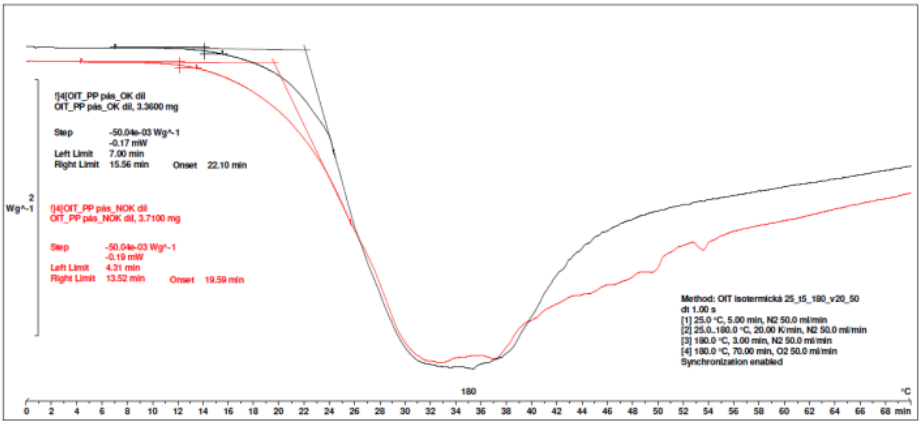

Fig. 11. Result from analysis of OIT

The graph shows (Fig. 11) a black line (new belt) and a red line (used belt from operation). Here, the values lying in the intersecting arc tangents (OIT) are compared. The OIT point of the used sample is slightly lower (i.e., it oxidizes faster), however, this value is not low enough to degrade the material and reduce its strength.

CT analysis that was carried out for a closer examination of the samples was using an industrial computed tomography system ZEISS METROTON 1500. The analysis was carried out to detect internal inhomogeneities in order to determine their numbers and sizes.

These inhomogeneities (puckering) have a negative impact on the durability of the affected areas, which together with other external influences can rapidly shorten the lifespan of the belt (Fig. 12).

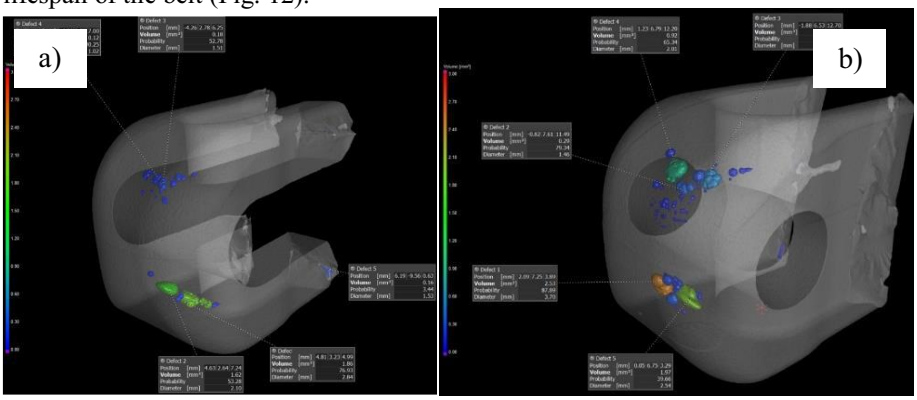

Fig. 12. Observed inhomogeneities in the outer edges of the linking segments of the new belt a) module with groove; b) module with hole

Next analysis of samples of a new belt were subjected to a microscopic analysis perpendicular to the dividing plane in the area where cracks occurred most frequently. The results, shown in the images, showed that the area above the dividing plane pre-

sents an inhomogeneous connection of the material resulting in cold junction (Fig. 13).

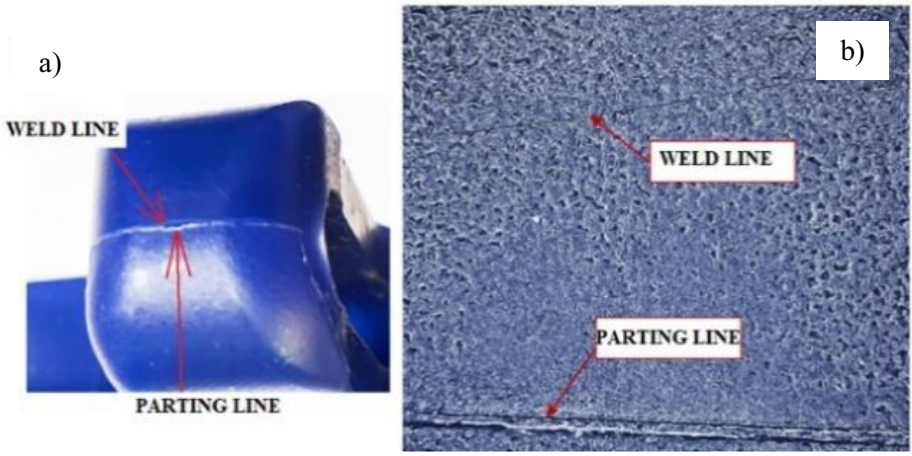

Fig. 13. Tensile strength test sample (parting line + weld line) a) segment of belt; b) detail

Further the red arrows in the image below (Fig. 14) shows clear outlines of puckering from which fractures of the belt expand (yellow arrows) all the way to the edge of the modular belt, until its breakage.

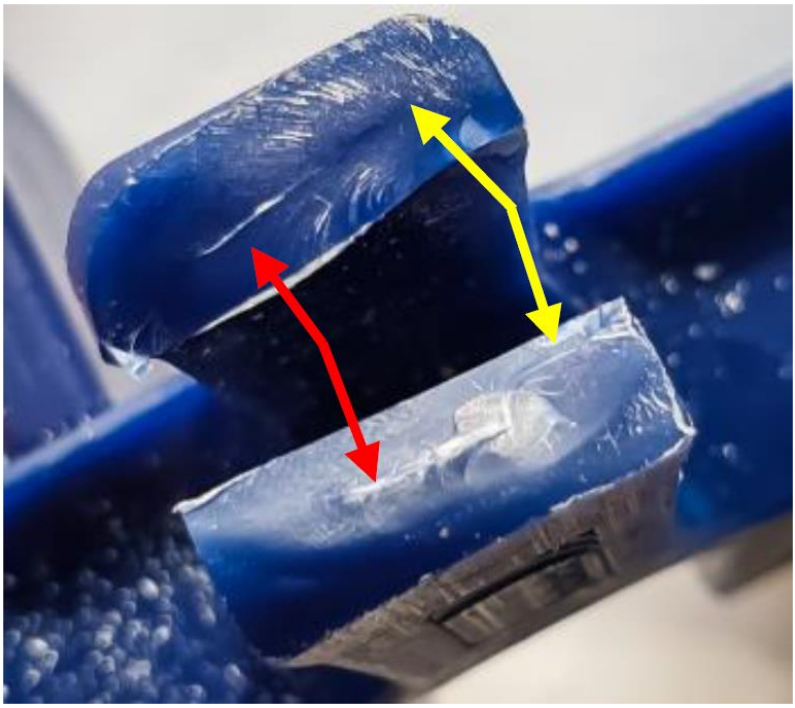

Fig. 14. Detail of puckering on cracked sample

The last analyse is mold flow analyse in Cadmould program, which can predict problems arising from incorrect construction of parts or improperly placed inlet. During the production process, the collision of two or more molten flow fronts and the subsequent solidification generates a region called the weld line, showing worse performances than the bulk material [6].

In picture below (Fig. 15) can be seen part of module of belt, which are the most stressed on the outer edge of the modular belt, it is possible to see the predicted weld lines in the places where the melt flows around the core, which creates a groove or circular hole, and returns to the face of the segment of module.

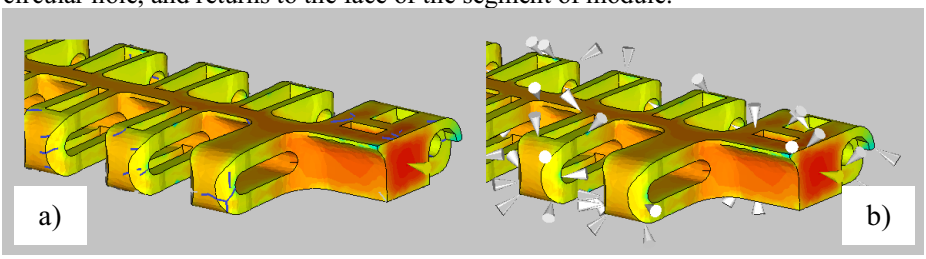

Fig. 15. Sample analysis a) weld lines; b) inhomogeneities

These places will always be problematic in terms of part construction. You can also see the possibility of creating inhomogeneities in the place of the front of the segment 9 of the module. Both of these theoretical premises are confirmed by the tests that have already been mentioned in the previous chapters.

Other places that show problematic defects were no longer the subject of investigation, as they were not confirmed as the weakest links in the case of a cracking modular belt.

For prompt reaction of solving issue with client was decided use hybrid construction of modular belt (Fig. 16). Outer parts of modular belt from PP material were changed to POM material and rod from POM material was changed to PA6.6 material.

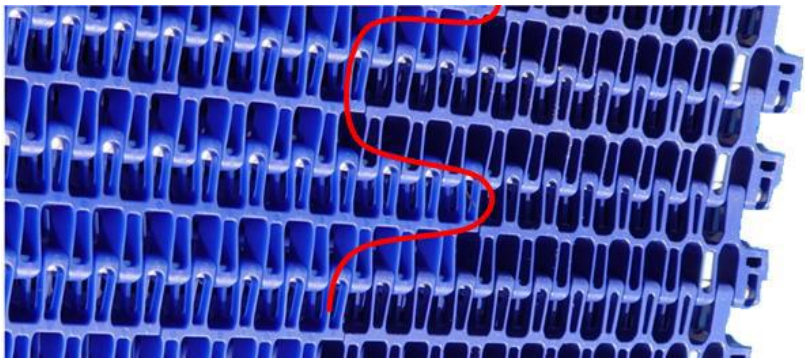

Fig. 16. Hybrid modular belt

On tensile tests were achieved higher loads than previous material (PP). However only material change is not avoiding of inhomogeneities and weld line.

6 Conclusion

This work deals with causes of the cracking segments by investigating possible structural defects on the spiral conveyor belt or its improper setup.

The result of this investigation was that no structural defect was found, nor were there any other aspects that could decrease the lifespan and durability of the modular belt. Proof of this conclusion laid out by the comparison of the measurements of the progressive tensile forces on the outer edge of the belt at an interval of one year.

The belt was tested in breaking point testing, where the results proved that the outer module of the belt used in operation lost more than 65% of its durability.

Several types of analyses were performed to identify problems with reduced durability at the end of the outer segment of the modular belt.

Material puckering and weld line were found on the outer segments of the modular belt in the area of the parting line. Mold flow analyse shows that occurring problems are arising due to incorrect design of modular belt or incorrect setting of injection molding machines.

All these aspects, together with the use of the belt in a certain, but permissible, long-term tension, lead to a rapid decrease in the durability of the belt in these and other places where puckering and weld line can occur.

Conclusion of this work is that modular belt cannot be use for long-term using in operation mode in fact of high risk of fatal destruction which stops whole production.

Although the material of outside parts of modular belt were changed for modules with higher strength, supplier of belts should avoid all these issues and get started to investigation of suitability of construction of molds.

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