Fraunhofer IPT

Study Report

Suitability of stainless steel and plastic belts for digital printing

Introduction

Digitalization is an important part within the current trends of the printing industry. While flexographic printing is still experiencing the highest growth in packaging printing with 15 %, digital printing technologies are growing fastest in commercial and publishing printing with up to 35 % share [1]. Cost-effectiveness, even for very short runs, due to a fast set-up and high flexibility are decisive advantages in favor of digital printing [2]. Most long-term investments are currently being made in the digital printing sector [3]. As in many other industries, the current trend in the printing industry is towards high flexibility and small batch sizes. Many printing technologies, such as offset printing, are designed for very large quantities and require a comparably high initial setup effort. In digital printing, on the other hand, it is possible to react flexibly and quickly to customer orders.

A core technology of digital printing is inkjet printing. A distinction is made between drop-on-demand (DoD) and continuous processes. In addition, single-pass or multi-pass print heads are used in the DoD process. Whereas in multi-pass printing the color image is produced with individual print heads for the typical CMYB (cyan, magenta, yellow, black) color tones, in the single pass process the various color tones are printed in one unit. Currently, the processes differ particularly in terms of speed. The substrates can be single pieces or endless material. Typical products used for this printing process include corrugated board, retail packaging or furniture panels. Inkjet printing achieves the highest print quality for images and luminosity of colors compared to all other printing processes [4].

In an industrial scaled machine setup, the substrates to be printed are placed on a continuously running conveyor belt, fixed to the belt via vacuum suction and moved through the inkjet printing unit while the print heads are stationary. The print quality which can be achieved depends on various factors. These include the belt run quality of the conveyor belt in transverse and longitudinal direction as well as the vertical vibrations emanating from the conveyor belt. Active or passive control units are used to optimize the belt run quality. Since the demand for digital inkjet printing on an industrial scale is continuously growing, high print speed and also high print quality are required. This study report analyzes the belt vibrations of a plastic and steel belt occurring at medium and high belt speeds.

The conveyor belt – an important element for print quality

The dynamic characteristics of conveyor belts are particularly crucial in applications with high requirements on precision, such as digital printing. The vertical vibrations that occur during operation are directly transmitted to the transported object and thus influence the printing process. Typically, the material used for conveyor belts for digital printing applications is steel and plastic. To compare these materials in terms of their suitability for digital printing, tests on belt vibrations were carried out using a conveyor belt test stand at the Fraunhofer IPT (Figure 1). The tests were executed at belt speeds of 30 to 300 m/min. In the first part of the tests, the vibrations were measured and analyzed with the belt in motion. Then it was investigated to what extent a local reduction of the belt vibrations in the process zone is possible. Finally, the influence of the belt tension on the vibration behavior was analyzed using the example of the steel belt. The same belt speeds were used for all tests.

On the test stand the conveyor belt is guided by three rollers: drive roller, deflection roller and tension roller. The required belt tension is set via two electric cylinders on the tensioning roller. It is also possible to regulate the lateral position of the conveyor belt with the same system. The current position of the belt is detected by two ultrasonic edge sensors behind the tension roller. An additional control of the lateral belt run can be realized with the deflection roller by tilting it around its axis. The substrate on the conveyor belt is usually fixed by means of vacuum suction. This is generated by a vacuum table located underneath the conveyor belt and guided through the perforation in the belt, so that a vacuum is created between the conveyor belt and the transported substrate.

To reduce vibration in the process, two air bearings were integrated in the vacuum plate along the direction of the belt run, as shown in Figure 2. Through a combination of an air film on the surface of the air bearings and a vacuum suction, objects that meet the minimum requirement for flatness and roughness can be guided friction-free on the air bearings. Via the vacuum grooves embedded in the vacuum plate, a vacuum suction can also be built up through the perforation in the belt and thereby fix substrates on the belt. The purpose of the air bearings is the reduction of belt vibrations locally and building up a frictionless guiding of the belt.

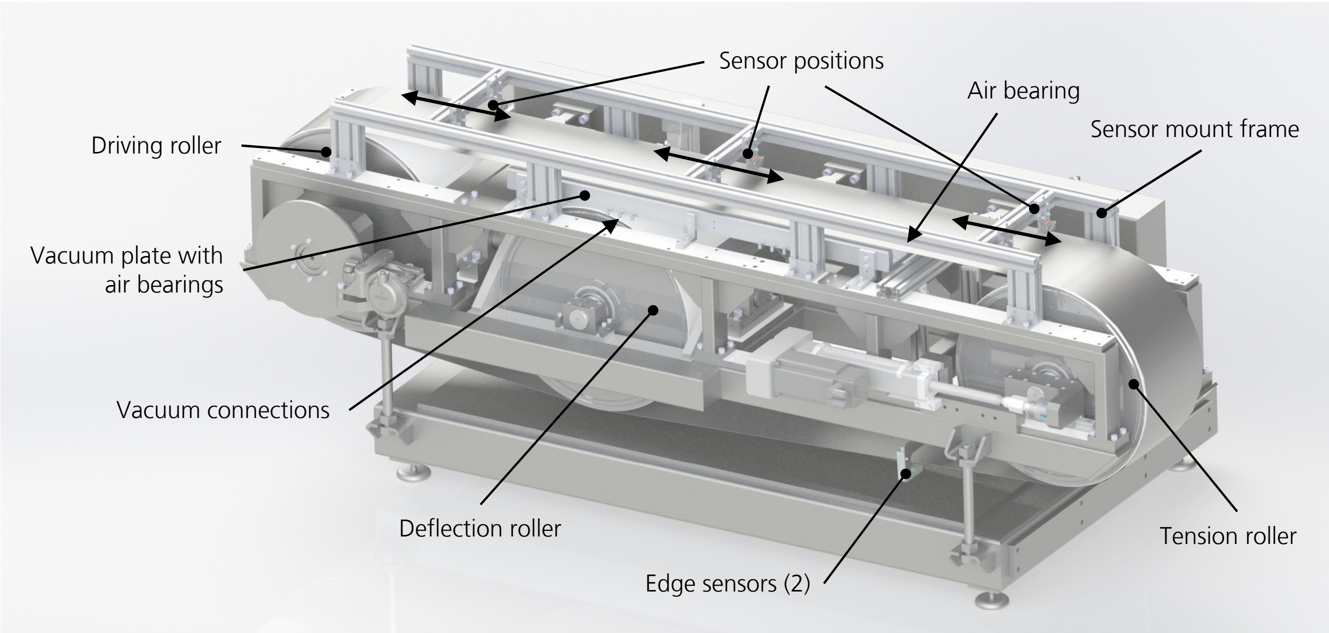

Figure 1: Setup conveyor belt test stand

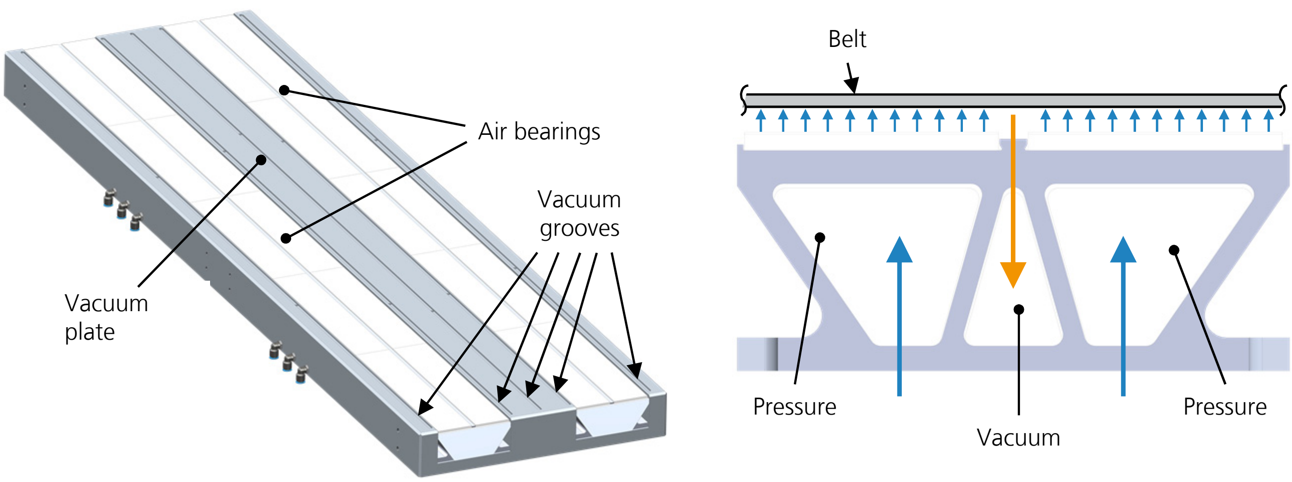

Figure 2: Integrated air bearings in vacuum plate positioned underneath the steel or plastic belt

Comparative vibration tests between steel and plastic belts

Conveyor belts are mainly made of plastic or steel (Figure 3). Plastic belts often offer a cost advantage and a wide range of designs. Steel belts are normally used for applications with special requirements such as high temperatures, high forces, or chemical processes. Also steel belts are particularly easy to clean and are therefore often used in the food industry. Up to now, both types of belts have been used for industrial digital printing. In addition to positioning in the X and Y directions, vertical vibrations of the conveyor belt in the printing area can lead to a negative influence on the print quality. These vibrations were investigated at the Fraunhofer IPT using belts suitable for digital printing. The properties of the steel and plastic belts can be found in Table 1. The different belt tensions (pre-tension) result from the properties of the belt materials. The pre-tension of the steel belt was determined based on a lifetime calculation and the manufacturer's empirical values.

	Steel belt	**Plastic belt**
Recommended belt tension [N]	5500	3000
Thickness [mm]	0.6	1.6
Width; length [mm]	310; 6568	310; 6568

Table 1: Properties of the investigated steel and plastic belt

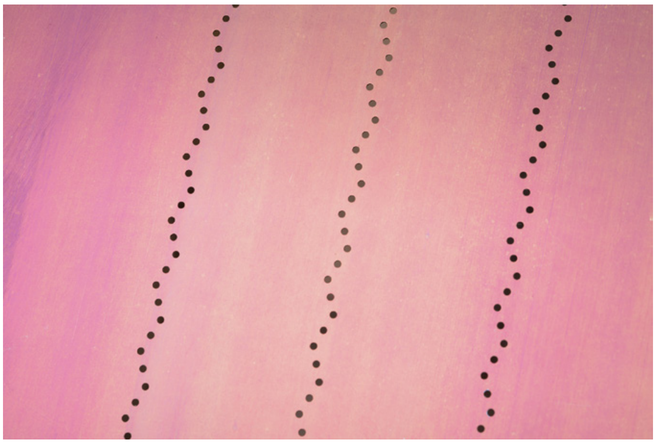

Figure 3: Belt with perforation for application of vacuum.

To measure the vibrations, a total of six laser distance sensors were used, which were arranged vertically above the conveyor belt. The repeatability of the distance sensors was tested in advance on a test device with samples of the respective belts and amounts to 6.8 µm (steel belt) and 8.6 µm (plastic belt). The positions of the sensors are shown in Figure 4. The vertical vibration of the conveyor belt creates a deviation in the position of the ink drops exiting the printhead. This deviation depends on various printing characteristics such as print or drop speed.

For comparison of the occurring vibrations, the amplitude range and the standard deviation are examined. The amplitude range is calculated by the difference between the maximum and minimum amplitude. The measurements are recorded and evaluated over a period of one minute at belt speeds ranging from 30 to 300 m/min in steps of 30 m/min. For a better overview the diagrams below just show the vibration data of the front sensors and belt speeds in steps by 60 m/min.

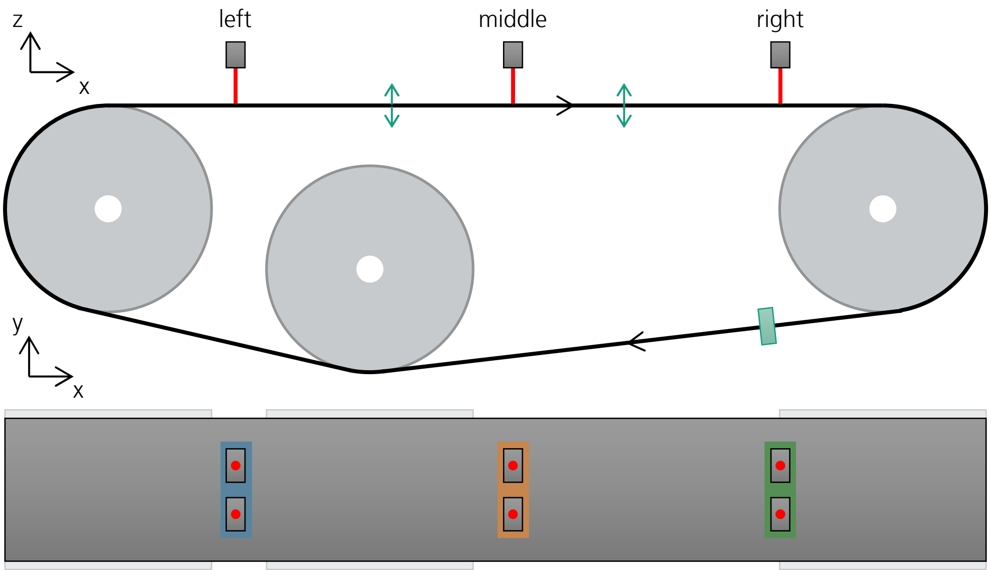

Figure 4: Arrangement of the laser sensors to detect the vertical belt vibrations shown as side and top view

Result: Steel belts vibrate significantly less than plastic belts

The vibration tests of the plastic and steel belts showed clear differences (Figure 5, Table 2). Both the amplitude range and the standard deviation of the recorded vibrations are four to six times higher for the plastic belt compared to the steel belt over all measured belt speeds. At a belt speed of 30 m/min, for example, an amplitude range of up to 450 µm was measured for the plastic belt, while this lies between 80 and 100 µm for the steel belt. The standard deviation is between 45 and 75 µm for the plastic belt and between 8 and 18 µm for the steel belt.

Belt speed	Amplitude range		Standard deviation	
[m/min]	Steel [µm]	Plastic [µm]	Steel [µm]	Plastic [µm]
30	90	420	12.5	58
90	68	350	9.5	49
150	68	308	9.5	48
210	55	285	8	45
270	50	235	8	43

Table 2: Average amplitude range and standard deviation comparing steel and plastic belt

Similar differences can be seen at higher belt speeds. The joint, especially of the plastic belt, has a large influence on the vibrations.

The largest vibrations of the plastic belt occur in the middle of the belt. Here, an increased standard deviation can be seen across all belt speeds. This effect is not noticeable for the steel belt.

In addition to the differences in the vibration behavior, a reduction in the occurring vibrations of both the amplitude range and the standard deviation with increasing belt speed can also be seen for both belts. The tests described here were carried out without air bearings.

In the next part of the study, air bearings were positioned underneath the belt in the process area as described before and the surface was aligned parallel to the belt. Figure 6 shows the comparison of the vibrations of the steel belt with and without the use of air bearings. Both the amplitude range and the standard deviation could be reduced by half compared to the previous setup, especially in the middle area above the

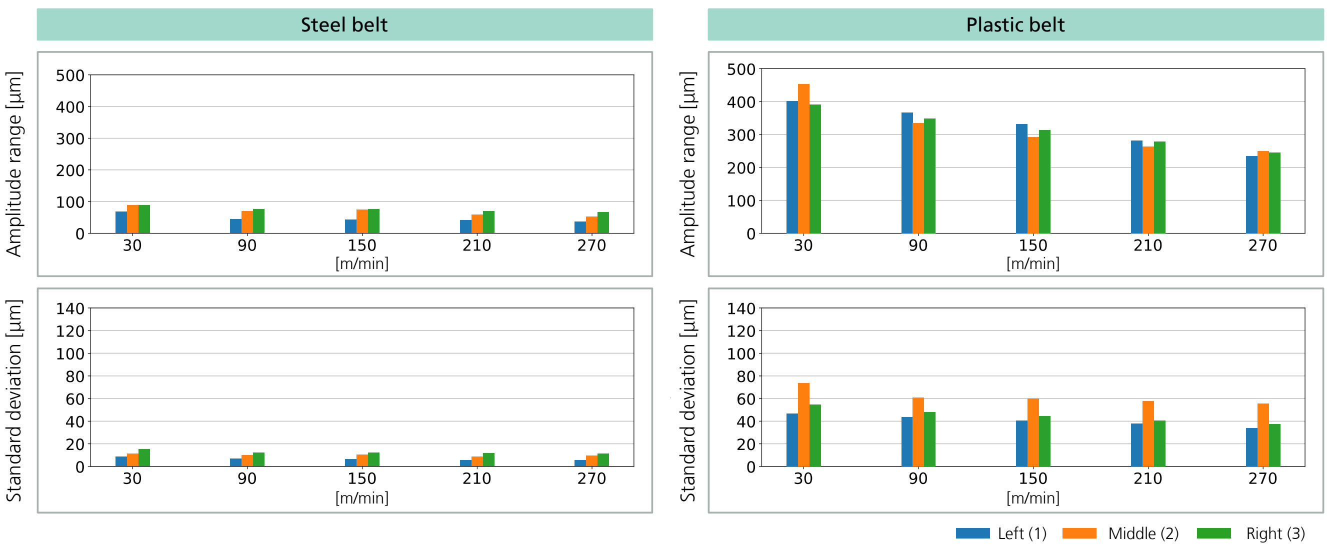

Figure 5: Amplitude range and standard deviation of steel and plastic belt at up to 300 m/min belt speed

air bearings. During the tests, no direct contact between the steel belt and the air bearings, for example through noise or abrasion, could be detected. The planned function of the air bearings and the formation of a separating air film to minimize wear could be successfully implemented using a steel belt. During the tests with air bearings, increased vibrations were found at the position of the right-hand sensors. However, a more detailed investigation of this behavior is not the subject of this study, as the focus is on the vibrations in the process zone (middle sensors).

The influence of the air bearings on the vibrations of the plastic belt can be seen in Figure 7. As with the steel belt, the air bearings visibly reduce the vibrations, especially in the middle area. In this area, a reduction of 30-40 % could be determined for the amplitude range and the standard deviation over the entire speed range. In contrast to the tests with the steel belt, the contact between the belt and the air bearings could not be completely separated when using the plastic belt. This could be determined by audible running noises.

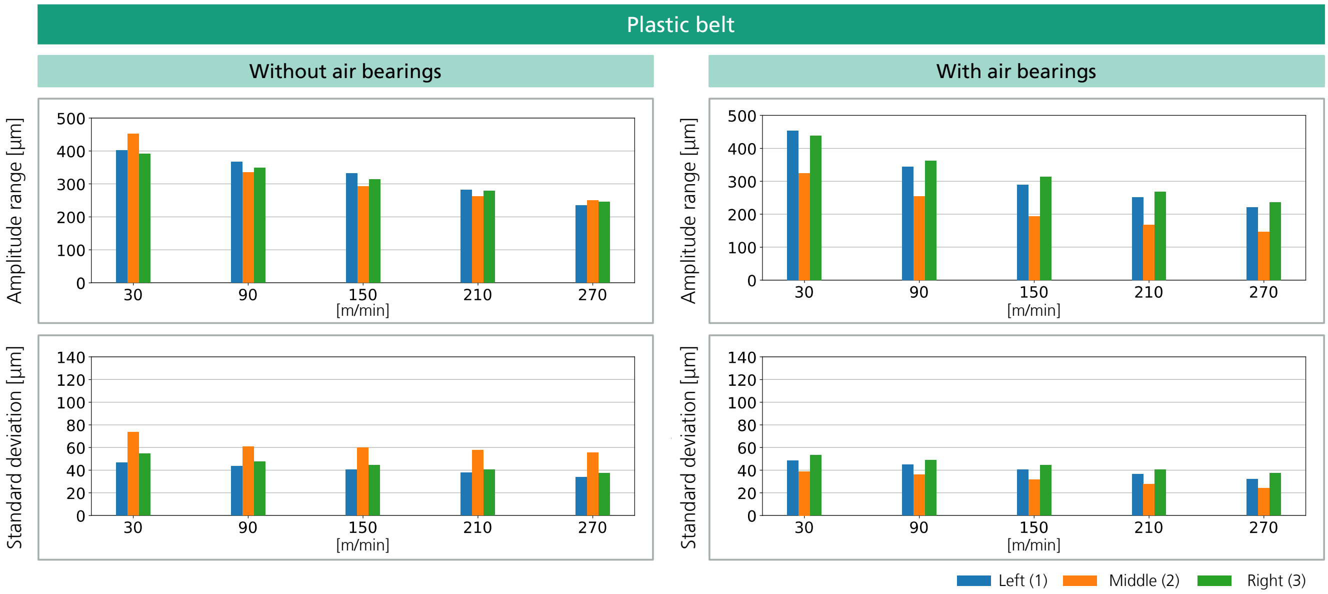

Figure 6: Amplitude range and standard deviation of steel belt at up to 300 m/min belt speed with and without air bearings

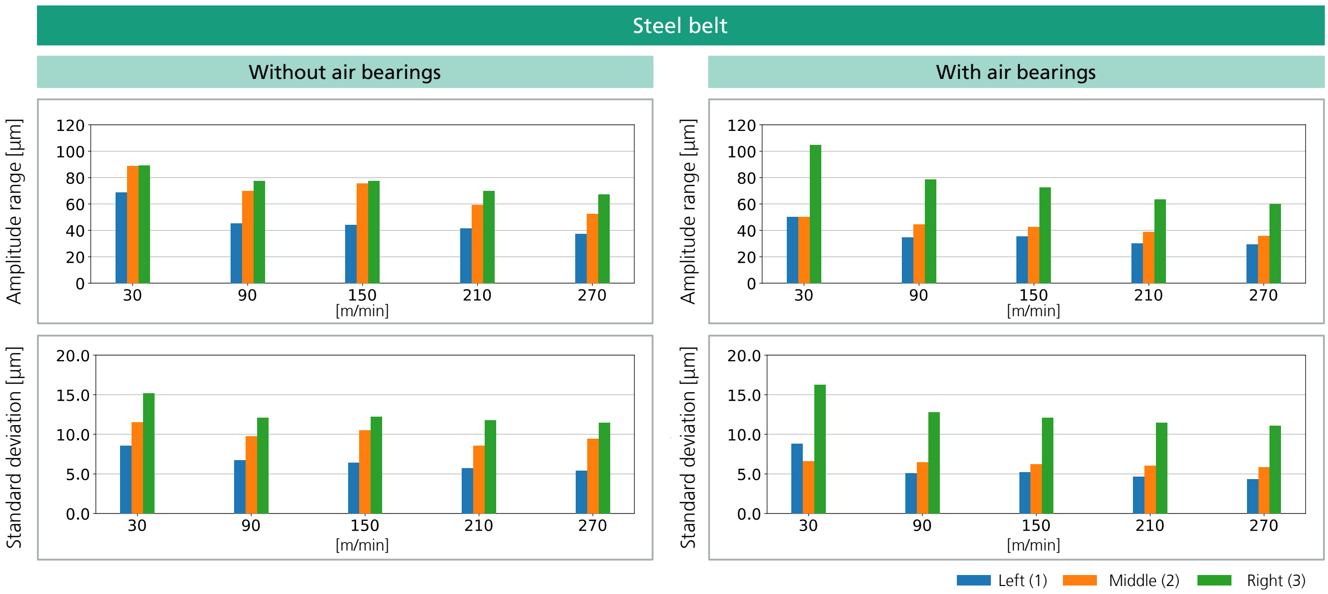

Figure 7: Amplitude range and standard deviation of plastic belt at up to 300 m/min belt speed with and without air bearings

It is suspected that this is due to the conditions of the belt running surface. The plastic belt used has a higher roughness on the underside (contact surface to the rollers), which means that the thin air film from the air bearings cannot be formed evenly. The steel belt has a very smooth surface on both sides. Surface contact with the air bearings is not recommended for continuous operation, as this can lead to increased wear of the material and thus to failure of the air bearings. The suitability of alternative plastic belts with a smooth running surface for use with air bearings to reduce vibrations is not excluded.

In the third part of this study, the influence of the belt tension on the vibration behavior of the steel belt is investigated. In addition to the tests carried out at 5500 N, the belt vibrations are investigated at belt tensions of 4600 N (25 MPa) and 6400 N (35 MPa). The result is shown in Figure 8. Overall, a reduction of the vibrations can be seen both in terms of amplitude range and standard deviation. Increasing the belt tension from 25 MPa to 30 MPa leads to a reduction of 15-25 % depending on the belt speed. A further increase of the belt tension to 35 MPa leads to a reduction of approx. 15 % for belt speeds up to 150 m/min. At belt speeds above 150 m/min, only minor changes are noticeable.

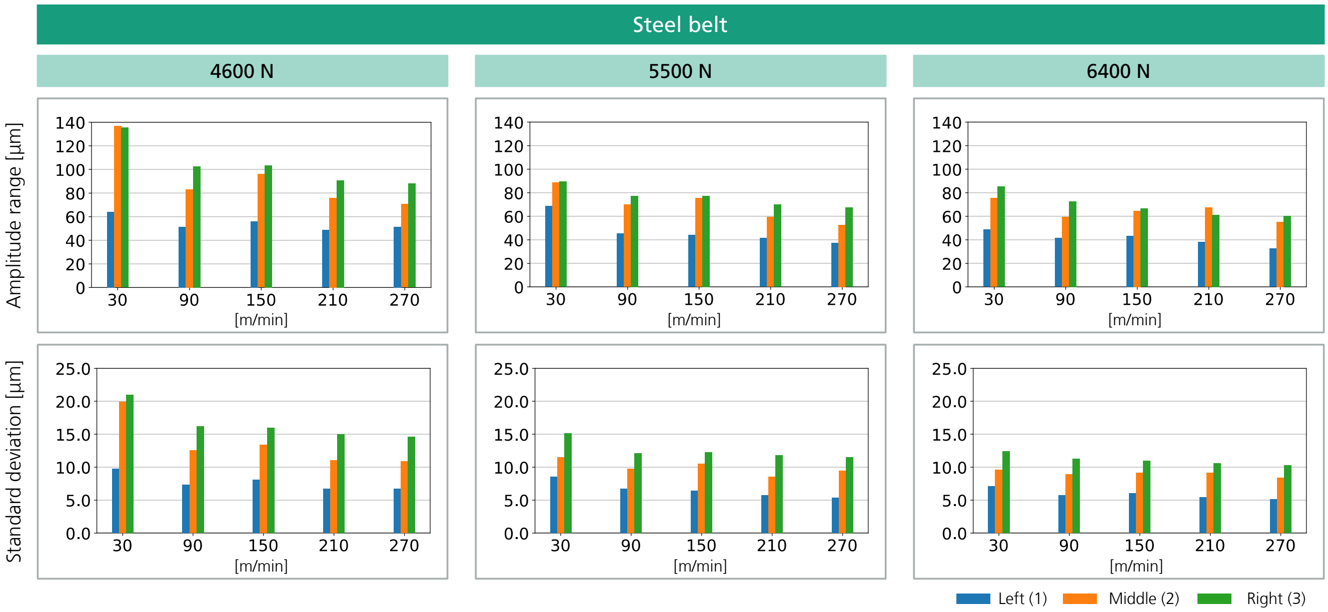

Figure 8: Amplitude range and standard deviation of steel belt at up to 300 m/min belt speed at different belt tensions

Conclusion

In this study the dynamic characteristics of steel and plastic conveyor belts regarding belt vibrations were carried out. The analysis showed major differences between the different materials as the measured vibrations of the plastic belt were four to six times higher compared to the steel belt. Furthermore, a reduction of vibrations with an increasing belt speed was determined for both belt types. We further investigated whether a local reduction of belt vibrations is possible by using air bearings. The tests showed a reduction for both belt types. The use of air bearings in combination with a steel belt could be carried out successfully. In contrast, running noises were detected with the plastic belt used. This is attributed to a non-stable air film due to a rough running surface. The suitability of alternative plastic belts with a smooth running surface must be examined. In the last part of the study a reduction of belt vibrations has been determined by increasing the of belt tension using a steel belt.

Authors

Laurin Blasius, M. Sc., Sebastian Dormann, M. Sc., Daniel Zontar, M. Sc., Prof. Dr-Ing. Christian Brecher

Literature

[1] drupa (ed.) (2020): Der 7. drupa Gobal Trends Report Executive Summary 2020. Available online: https://www.drupa.com/cgi-bin/md_drupa/lib/all/lob/return_download.cgi/7th_drupa_Global_Trends_Executive_Summary_German.pdf?ticket=g_u_e_s_t&bid=5541&no_mime_type=0 (accessed on: 10/10/2022).

[2] Zapka, W. (2018): Handbook of Industrial Inkjet Printing. Springer-Verlag

[3] drupa (ed.) (2022): 8. drupa Global Trends Report 2022 - Executive Summary. Available online: https://www.drupa.de/cgi-bin/md_drupa/lib/all/lob/return_download.cgi/8th_Global_Trends_Executive_Summary_DE.pdf?ticket=g_u_e_s_t&bid=7251&no_mime_type=0 (accessed on: 10/10/2022).

[4] Bühler, P., Schlaich, P., Sinner, D. (2018): Druck. Druckverfahren – Werkstoffe – Druckverarbeitung. Berlin: Springer Vieweg. DOI: 0.1007/978-3-662-54611-6.

Contact

Laurin Blasius
Phone +49 241 8904-138
laurin.blasius@ipt.fraunhofer.de

Fraunhofer Institute for
Production Technology IPT
Steinbachstrasse 17
52074 Aachen
Germany
www.ipt.fraunhofer.de

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