The Damping of Vibrations at the Transfer Points of Belt Conveyors Used in the Construction Industry

Leopold Hrabovský[1)*], Jiří Fries [2)]

[1)*] VSB - Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Machine and Industrial Design, 17. listopadu 2172/15, 708 00 Ostrava - Poruba, Czech Republic; email: leopold.hrabovsky@vsb.cz; ORCID: https://orcid.org/0000-0003-3700-8041

[2)] VSB - Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Machine and Industrial Design, 17. listopadu 2172/15, 708 00 Ostrava - Poruba, Czech Republic; email: jiri.fries@vsb.cz; ORCID: https://orcid.org/0000-0001-9776-6878

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Abstract

Construction debris removed from demolished buildings or loose building materials are in many cases transported from mining sites to the places of their processing using belt conveyors. When transporting building materials over longer distances, transport routes are used, i.e. the required number of belt conveyors arranged one after the other. The grains of the transported material are projected at an angle through the end drum of one belt conveyor and fall on the working surface of the other belt conveyor. At the points of material grain impact, the conveyor belt is supported by traditional fixed belt conveyor idlers or by so-called impact bed conveyors. Traditional belt conveyor idlers, fitted with impact rollers, are usually installed in the places of the transfer points of belt conveyors arranged one after the other. These can be used mainly for the horizontal, but also the vertical transport of bulk or piece building materials. The grains of bulk building materials falling on the surface of the conveyor belt at the transfer points or hoppers damage the covering rubber layer and the supporting frame of the conveyor belt and generate dynamic forces that are transferred to the load-bearing track of the conveyor belt. This paper presents a belt conveyor idler of a special design, which consists of placing plastic brackets in structurally modified trestles. Impact rollers can partially absorb the dynamic forces generated by the high potential energy of the building material grains. The paper presents the detected forces acting in the places of mechanical attachment provided by experimental measurements carried out on a laboratory belt conveyor idler attached to the aluminium frame, which simulates the load-bearing carrier track of a conveyor belt. During experimental measurements done on laboratory equipment made of drawn aluminium profiles, a mechanical shock occurs between the weight and the rubberized shell of the impact roller. The weight falls in a free fall from a known height on the casing of the impact roller, thus deriving a dynamic force. This is transferred via the roller axis into the idler and through its supports to strain gauge force transducers, which are mechanically attached between the frame of the laboratory equipment and the supports of the belt conveyor idler. From the values of forces obtained when providing repeated measurements under the same conditions and detected by strain gauge force sensors, values were recorded in the tables presented in the article, and the mean values of the forces generated by the incident weight on the rubber surface of the impact roller were calculated.

Keywords: *head drive station, tail pulley, tensioning station, transport idlers, conveyor belt*

1. Introduction

In many areas of industry, including construction, the handling of bulk materials [1] is done by continuously operating transport systems that are known as conveyor belts [2]. Belt conveyors are used for the transport of bulk materials in a horizontal or inclined direction, with special belts up to an angle of 30 deg [3], [4].

A belt conveyor is a conveyor whose carrying and pulling element is an endless conveyor belt circulating between the drive drums and tail pulley (or between two tensioning pulleys and a lower drive loop) supplemented with other structural elements needed for its operation. The advantage over other transport facilities is smooth transport with a high transport performance.

The standard [5] classifies belt conveyors depending on the design of the load-bearing structure as follows:

a) the stable, load-bearing steel structure firmly attached to the foundation,
b) movable and portable for small transport quantities and short lengths,
c) adjustable, characterized by a high conveying speed and long transport length.

According to their length, belt conveyors can be divided into short (up to 20 m) or long (up to 5 km). Belt conveyors can be further divided into horizontal (± 3 deg) and inclined, regarding their inclination, which significantly affects their design.

The basic structural elements of the belt conveyor are, according to the standard [6] the head drive station, tail pulley, tensioning station, transitional idlers, conveyor belt and other supplementary and protective equipment.

Although the conveyor belt can be made of different materials, the most commonly used is a multi-layer belt with a top layer of PVC, PU, rubber or silicone, with a textile insert, which usually consists of cotton, rayon, polyester polyamide or a combination of polyester and polyamide. Extremely stressed and loaded belts have a combined reinforcement of polyamide with steel cables. The conveyor belt is usually supported along the entire length of the conveyor belt run by a slideway or transitional and return idlers. The function of these support (transitional) idlers is to guide the conveyor belt with the material between the end drums.

In many cases, the construction of new residential or industrial buildings is preceded by the demolition of obsolete and currently unsuitable buildings. The demolition of buildings brings with it the requirement to relocate a large amount of rubble, in most cases are bricks and masonry, which in the past were almost exclusive building materials.

The rubble, which is the remnant of the demolished buildings, must be removed from the place of its origin. When handling, loading or depositing such rubble in a landfill, belt conveyors arranged in series are used to form a transport line.

During the transport of building materials by conveyor belts, undesirable phenomena such as noise and vibrations are created, which are a side effect of a large number of rotating elements. These components are the conveyor rollers and idlers supporting the conveyor belt in the loading and return conveyor belt run. In the places of the transfer points (but also in the places where the construction debris is fed into the so-called “hopper”, e.g. by a shovel or bucket loader), undesirable dynamic forces arise induced by the potential energy of the falling grains.

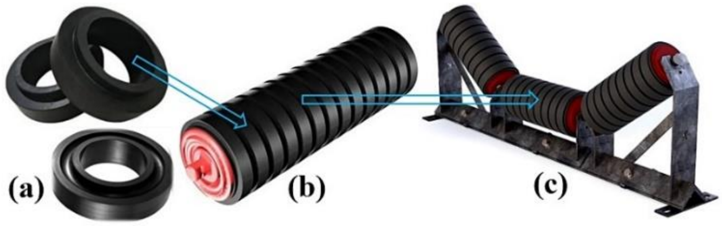

Fig. 1. (a) Rubber ring, (b) Conveyor belt impact roller, (c) Troughing impact idler.

The effort to reduce the large dynamic effects of the falling material grains at the transfer points or hoppers led to the design of the so-called impact rollers. These differ structurally from conveyor rollers in that a series of rubber rings are slid onto their outer steel casing, see Figure 1. The rings have certain thicknesses and widths, thus, these rollers can absorb part of the dynamic effects of the falling grains of the material in the place where the conveyor belt is supported by these impact rollers.

2. Laboratory equipment. Traditional and a special belt conveyor idler structure

Laboratory equipment, used to detect the dynamic forces transmitted to the frame via the fixed belt conveyor idler from the impact of the load (simulating the grain of the transported material) on the rubberized casing of the impact roller, is presented in Figure 2.

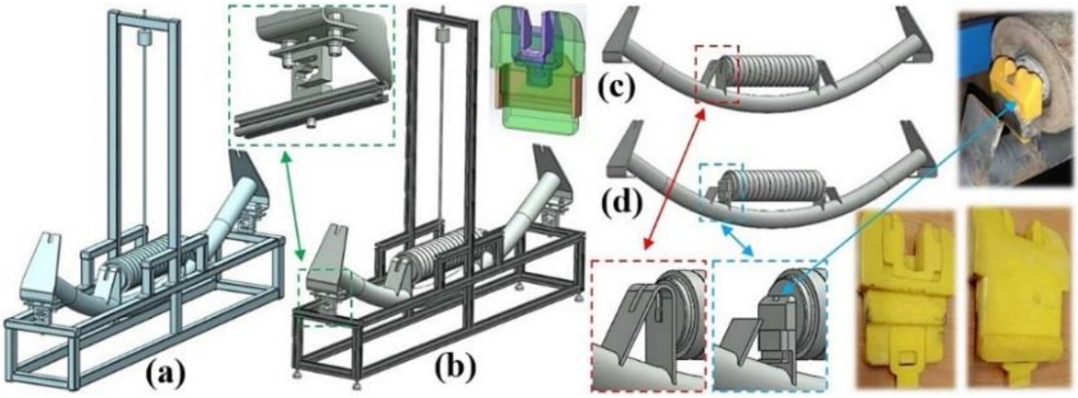

Fig. 2. Laboratory equipment (a) welded frame, (b) bolted frame, (c) standard troughing idler, (d) impact troughing idler.

The fixed belt conveyor idler is fastened with screw connections M8x25 to two strain gauge force sensors and these, with the help of the M8x50 screw connections, to the frame of the laboratory equipment. The original structural design of the laboratory equipment frame (Figure 2(a)) was designed as a two-part welded structure assembled from steel closed profiles with a rectangular cross-section (with dimensions of 40x30 mm and a wall thickness of 1.5 mm). Due to the laboriousness of the production and the need to paint the welded structure, it was proposed that the frame of the laboratory equipment be assembled from aluminium profiles with transverse dimensions of 30x30 mm, a production designation MI 30x30 B8, supplied by the company MAREK Industrial a.s. (Figure 2(b)).

Figure 2(c) presents firm troughing idlers with a traditional design. The flattened ends of the impact roller axis are inserted into the notches made in the steel trestles.

Figure 2(d) shows a structurally modified fixed roller support. The design modification consists of the fact that to the vertical part of the steel trestle (which is cut into two parts), a holder is welded, into which the polyurethane bracket is inserted (Shore 90 hardness), into which the flattened part of the impact roller axis end is inserted.

This laboratory equipment (Figure 2(b)) was created for the practical verification of the theoretical assumption that by using impact rollers it is possible to reduce the magnitude of the dynamic force transmitted to the belt conveyor idler, generated by the material grain impact on the working surface of the conveyor belt at the transfer points and hoppers.

To reduce the transfer of dynamic force to the supporting structure of the belt conveyor, which is simulated by an aluminium frame in the laboratory equipment, a structural modification of the trestle of a belt conveyor idler was created (Figure 2(d)), consisting of polyurethane brackets between the steel trestles and the flattened ends of the impact rollers.

An impact roller was used during the experimental measurements carried out on the laboratory equipment (manufactured by DUBA-DP s.r.o.) with the outer diameter of the rubber lining 133 mm.

The purpose of the experimental measurements was to obtain the values of the dynamic forces transmitted from the belt conveyor idler to the frame of the laboratory equipment, generated by the known mass impact on the rubberized casing of the experimentally tested impact roller. Both supports of the belt conveyor idler were mounted on strain gauge force sensors (AST-250 kg, produced by FORMÁT 1 s.r.o.), which detect the time waveforms of the force caused by the weight impact on the roller casing, transmitted through the roller axis to the location of both supports of the belt conveyor idler. Signals from both strain gauge force sensors were processed by measuring DEWESoft DS-NET apparatus [7] and displayed using a PC monitor and DEWESoft X2 SP5 software environment, see Figure 3(a).

Experimental measurements were carried out in a total of two variants, which correspond to the use of a traditional or modified belt conveyor idler, fitted with an impact roller with a diameter of 133 mm.

3. Experimental measurements procedure

Prior to the experimental measurements carried out on the laboratory equipment, both strain gauge force transducers were calibrated. The calibration of the sensors was carried out by loading the sensor (each separately) with a mass of known weight mz [kg] (weight Gz [N]), see Figure 3(b).

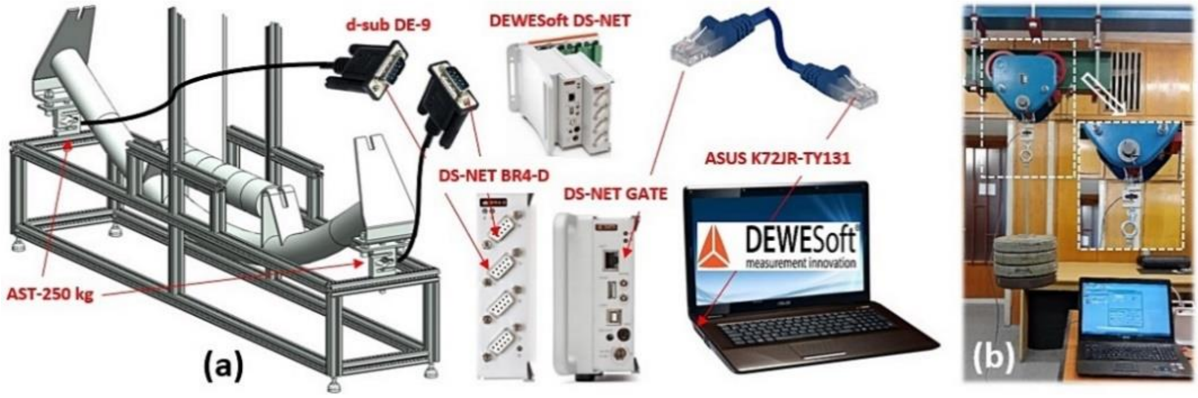

Fig. 3. (a) measuring chain of laboratory equipment, (b) calibration of strain gauge force sensors with weights of a known mass.

After the assembly of all parts on the laboratory equipment, both strain gauge force sensors were connected to the DEWESoft DS-NET measuring apparatus, and using a network cable with RJ45 connectors, it was linked to a PC (ASUS K72JR-TY131) with DEWESoft X2 SP5 software installed, see Figure 3(a). Using a free fall, the weight of mm = 1 kg was repeatedly lowered from a height H = 0.9 m on the casing of the conveyor or impact roller. At the moment of the impact of the weight on the roller, the excited impact force was detected in a time t [s] by strain gauge force transducers, and then processed by a measuring apparatus and recorded on a PC disk.

Experimental measurements and the measured values of the dynamic force.

Using laboratory equipment (Figure 4), experimental measurements were carried out for these two variants: a) a fixed load-bearing bench with a traditional design (steel roller bracket) + an impact roller with a rubber casing (see Table 1), b) a fixed load-bearing bench of a special design (a polyurethane roller bracket) + an impact roller with a rubber casing (see Table 2).

Fig. 4. Implemented laboratory equipment.

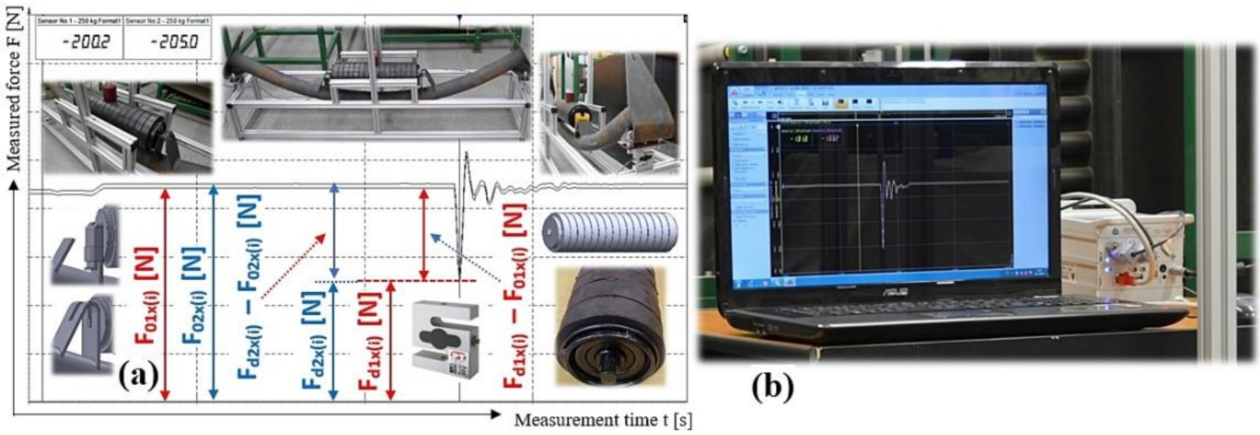

Fig. 5. Graphical recording of detected forces by strain gauge force sensors.

During experimental measurements, strain gauge force sensors No. 1 (No. 2) detected the following:
- initial forces F01x(i) [N] (F02x(i) [N]), where “x” defines the type of roller axis holder (s - steel, p - rubber),
- maximum forces Fd1x(i) [N] (Fd2x(i) [N]) when the weight hits the rubber casing of the impact roller.

The experimental measurement of forces F01x(i) [N] (F02x(i) [N]) and Fd1x(i) [N] (Fd2x(i) [N]) For each of the two variants, it was repeated five times (i = 1÷5) under comparable external conditions, with the same measuring instruments and the same measuring apparatus. The values of the measured forces obtained n times by repeated measurements were recorded in the tables (see Table 1 and Table 2). Of the five measured force values F1(i) [N] the arithmetic mean F1s [N] was calculated and extreme error k1,α,n [N], where α = 1% - Student's risk distribution. The measurement result in the shape of F1 = F1s ± k1,1%,5 [N] is listed in the last line of Table 1.

Tab. 1. Steel impact roller bracket.

impact roller, sensor “1”			impact roller, sensor “2”		
$F_{01s(i)}$ [N]	**$F_{d1s(i)}$ [N]**	**$F_{1(i)} = F_{d1s(i)} - F_{01s(i)}$ [N]**	**$F_{02s(i)}$ [N]**	**$F_{d2s(i)}$ [N]**	**$F_{2(i)} = F_{d2s(i)} - F_{02s(i)}$ [N]**
130.5	217.9	87.4	133.9	221.6	87.7
130.7	217.7	82.7	134.0	220.3	84.1
130.6	214.3	83.7	133.9	216.0	82.1
130.7 [1]	213.4 [2]	87.0	133.8 [1]	217.9 [2]	86.3
130.8	215.8	85.0	134.1	218.5	84.4
F_{1s}		85.16	F_{2s}		84.92
$k_{1,1\%,5}$		2.84	$k_{2,1\%,5}$		2.89
$F_1 = F_{1s} \pm k_{1,1\%,5}$		**85.2 ± 2.8**	$F_2 = F_{2s} \pm k_{2,1\%,5}$		**84.9 ± 2.9**

Figure 6 presents a time record of the measured forces, which is the weight of the belt conveyor idler with a traditional design (Figure 2(c)), in which the impact roller is attached.

Figure 6(a) indicates in its upper right part the values of the measured initial forces F01s(4) [N] and F02s(4) [N]. These initial values define a measurement state where no load from the weight is applied to the impact roller.

Figure 6(b) in its upper right-hand part, indicates the values of the measured forces Fd1s(4) [N] and Fd2s(4) [N] in its upper right-hand part, which define the moment of impact of the weight acting on the rubberized casing of the impact roller.

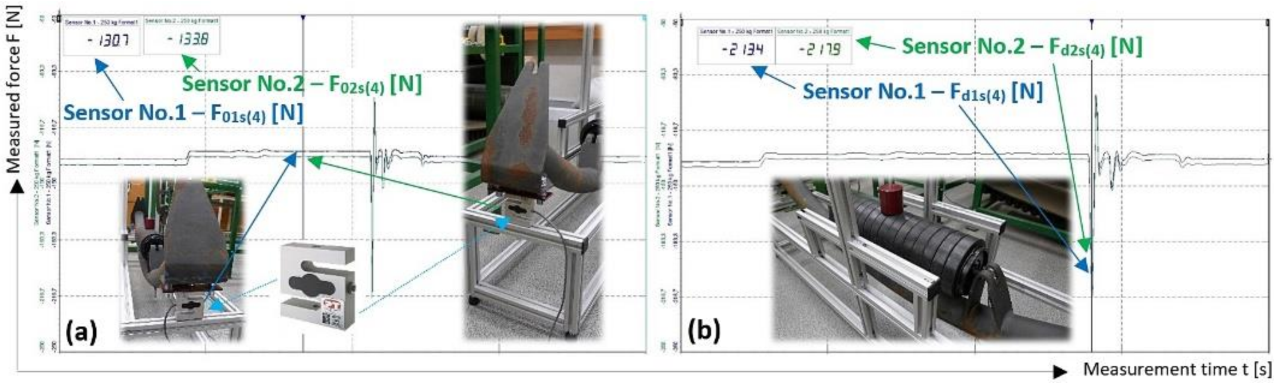

Fig. 6. Recording of measured forces (a) F01s(4) [N] and Fd1s(4) [N] force sensor No. 1, (b) F02s(4) [N] and Fd2s(4) [N] force sensor No. 2.

Tab. 2. Plastic impact roller bracket.

impact roller, sensor “1”			impact roller, sensor “2”		
$F_{01p(i)}$ [N]	**$F_{d1p(i)}$ [N]**	**$F_{3(i)} = F_{d1p(i)} - F_{01p(i)}$ [N]**	**$F_{02p(i)}$ [N]**	**$F_{d2p(i)}$ [N]**	**$F_{4(i)} = F_{d2p(i)} - F_{02p(i)}$ [N]**
131.6	204.7	73.1	132.9	207.0	74.1
131.6 [1]	209.7 [2]	78.1	133.1 [1]	212.1 [2]	79.0
131.3	208.5	77.2	132.2	212.8	80.6
130.8	208.7	77.9	132.8	209.9	77.1
131.4	207.4	76.0	132.7	211.4	78.7
F_{3s}		76.46	F_{4s}		78.16
$k_{3,1\%,5}$		2.65	$k_{4,1\%,5}$		2.65
$F_3 = F_{3s} \pm k_{3,1\%,5}$		**76.5 ± 2.7**	$F_4 = F_{4s} \pm k_{4,1\%,5}$		**77.9 ± 3.2**

Figure 7 presents a time record of the measured forces, which is the weight of the belt conveyor idler with a special design (Figure 2(d)), to which the impact roller is attached.

Figure 7(a) in its upper right part indicates the values of the measured initial forces F01p(2) [N] and F02p(2) [N] that define the measurement status, when there is no load on the impact roller from the weight.

In the upper right corner of Figure 7(b), the values of the measured forces Fd1s(4) [N] and Fd2s(4) [N] are given, representing the moment of measurement when the weight fell on the rubberized casing of the impact roller.

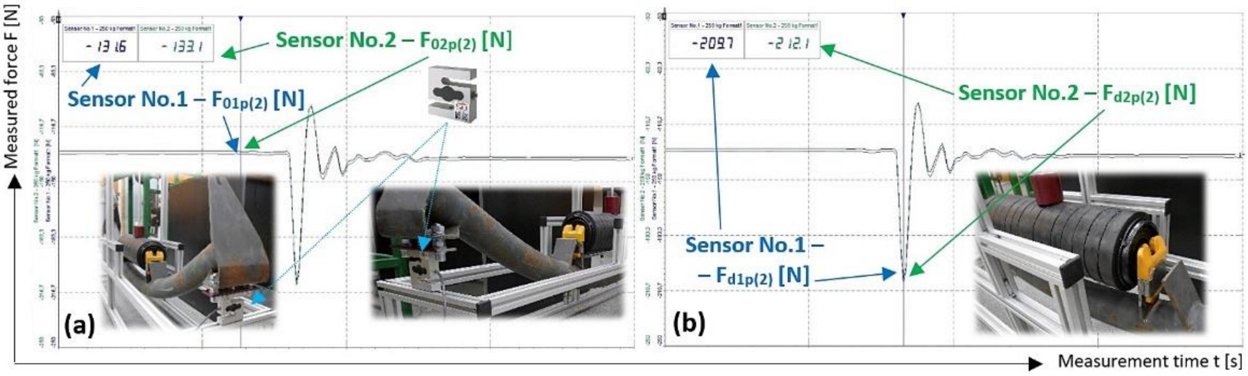

Fig. 7. Recording of measured forces (a) F01p(2) [N] and Fd1p(2) [N] taken by the force sensor No. 1, (b) F02p(2) [N] and Fd2p(2) [N] by force sensor No. 2.

4. Conclusion

The article presents a test rig that was structurally designed and assembled in the R&D laboratory, at the Department of Machine and Industrial Design, Faculty of Mechanical Engineering, VSB-Technical University of Ostrava. The test device allows you to measure and record the values of the forces of the incident weight impacting the rubberized rings mounted on the casing of the impact roller. The flattened ends of the impact roller axis are housed in a steel trestle of the belt conveyor idler with the traditional design or in plastic brackets that are attached to the structurally modified trestles of the belt conveyor idler with a special design.

Provided experimental measurements have proven the correctness of the assumption that the reduction of vibrations transmitted to the frame of laboratory equipment (simulating the load-bearing structure of a belt conveyor transfer point) can be achieved by installing rubber brackets for the impact roller axis placed into the belt conveyor idler.

The measurements show that the maximum force excited by the impact of the weight acting on the rubberized ring of the impact roller is transferred from the specially designed belt conveyor idler into the frame of the laboratory equipment and reaches 89.8% (91.8%) values compared to usage of the traditional belt conveyor idler.

The experimental measurements carried out on the laboratory equipment have shown that it is possible to reduce vibrations generated by the falling grains of the conveyed material on the surface of the conveyor belt transmitted to the load-bearing structure of the belt conveyor supported by impact rollers mounted on the belt conveyor idler. The proposed solution characterized by placing the axis of the impact roller in plastic brackets inserted into the modified steel trestles of the belt conveyor idler, can be used in practice to reduce the vibrations and attenuation of the impact forces caused by the impact of material grains at the transfer points of the belt conveyors.

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