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Dimensioning and Application of Belt Conveyors with Intermediate Belt Drive (T-T System)

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Summary

For the continuous handling of bulk materials, free of transfer points, belt conveyors with belt-to-belt intermediate drives are of advantage. Apart from controlling belt tensions in long and steep, ascending and descending conveyors, safe belt tracking horizontal curves with the smallest radii can be realized with the aid of TT intermediate drives. The prerequisites for this are thorough investigations of loading and operating states for the belt conveyor system with safe operation and economical dimensioning. A simulation program adapted to this problem permits optimization of plant data using a process video system and a digital computer.

1. Introduction

Developments in the field of bulk materials handling using belt conveyors have been marked in recent years particularly by the increase in performance. Greater volumes of material demand greater belt strengths, as well as larger motor outputs which have to be transmitted to the belt by friction. Conventional systems are equipped with end pulley drives which have to handle all driving forces. With the introduction of intermediate drives, which are arranged along the conveyor route thus limiting the belt tensions, further possibilities are offered in the application of this bulk materials handling method.

By decreasing the number of transfer points in a conveyor system, wear of the carrying side of the belting, abrasion of material and dust development can be reduced, as well as investment and operating costs. In conventional systems, high-strength belting, heavy framework, large pulleys and drive units are necessary to withstand the high resistance forces in the plant.

Limits are set to the steady growth of individual plant components for economical, technological and physical reasons. Particular difficulties are involved when making the endless high-strength steel cord belting, to ensure that the belt joins have a strength which is nearly as high as the intact belting. As a result of the great weight of the belt itself, which can be more than double (carrying and return run) that of the material load, an essentially horizontal, long-distance belt conveyor system with end pulley drives for instance requires a high rating when operating without load. The hauling heights or lengths of steep ascending conveyors are limited by the great downward force components resulting from the weight of the belt return run. For transmission of the peripheral force on the head drive, therefore, there is only the difference between permissible belt tension and downward force available, where the necessary belt tension for transmitting peripheral force is only a fraction of the downward force.

Particularly in underground mining, the application of intermediate drives and thus the possibility of smaller drive units in conjunction with belts with less strength brings many more advantages than the simple head drive design. The expensive excavation of large pits for head drive terminals is therefore unnecessary in the case of stationary conveyors covering long distances and hauling heights. Transportation and spare parts stockkeeping of small drive components and belting of less strength with lighter weight are more favourable in cost than larger units.

The availability of a conveyor system equipped with several intermediate drives can be more highly rated than that of a conventionally driven system with large drive units. If a small drive unit breaks down, plant operation is continued with correspondingly reduced material flow, so that absolute standstill does not necessarily occur. The obligatory repair can be carried out quickly, at less cost and involving less work.

Another great advantage is offered by intermediate drives in extensible underground mine and stockpile conveyors which are lengthened at regular intervals. The belt quality is kept at its initial length until final extension and the head drive terminal does not have to be extended. With the fabric belts which can be used for the intermediate drive design, the necessary belt joins can be made simply and quickly by means of hook connectors. Many plants of this kind have been in use for many years in coal mines.

From the varied possibilities of designing intermediate conveyors, those based on the principle of belt-to-belt drive (TT drive) have made their way in practice. Standardized drive units and belting are used here for the booster belt drive of conventional design with one or more pulleys. An economi-

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cal and reliable system results for practical use, due to the uncomplicated drive construction and by omitting special elements.

2. Computer Simulation of Belt Conveyor

For safe, trouble-free belt conveyor operation with TT intermediate drives, thorough examinations [1, 2] are essential for planning and dimensioning. The design criteria of belt conveyors with conventional drives are inadequate here, because usually only the nominal load state has to be taken as a basis. When positioning drives along the conveyor route, the nominal load as well as partial load states have to be examined for the different operating states so that the plant is correctly designed. This is not only necessary for dimensioning the carrying belt but also for the driving belt. For instance, the overall length of the driving flights cannot be determined without stipulation of belt quality and of the installed rating in the head drive. A simulation computer program has been prepared for optimizing the belt conveyor. This computer calculates and displays graphically all the necessary loading und operating conditions necessary for dimensioning. Two computer systems are available for this purpose, one digital simulation computer unit and a process video system (PVS) [3]. These two systems differ in the following points:

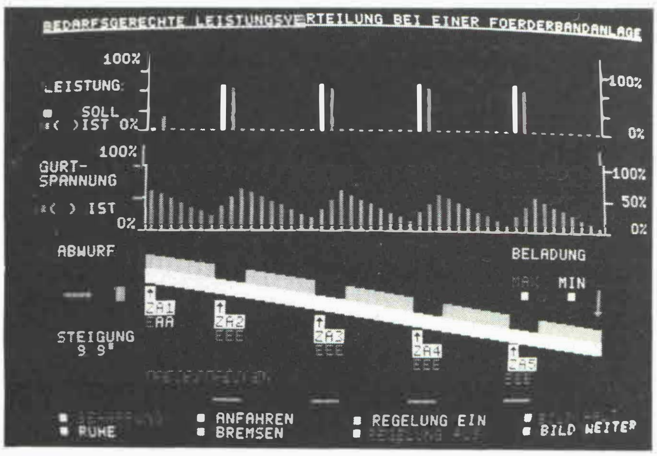
Digital simulation registers in a conventional way each set operating state of the belt conveyor system with the aid of computer print-outs, including all the data necessary for dimensioning, whereas the process video system displays the momentary calculated results on a screen — although, in order to keep the scope clear, only the main data such as the actual drive output of the motors, the belt tension plotting, loading and operating states, as well as the schematic plotting of the belts with positioning and length of the driving belts are shown. In this way, for instance, changes in belt tensions and in motor outputs corresponding to the flow of material along the system can be followed up when operating with full load, when emptied and in case of interruptions in material feed.

Apart from the dimensions required for belt systems with conventional drives, the TT intermediate drive positions along the conveyor route and driving belt length must be optimized above all in order to ensure operational safety, regardless of operating states. If it becomes apparent that, with a certain operating state for instance, the best position of an intermediate drive has not been selected, it can be moved to a more suitable place by inserting data into the computer. Other parameters for improving operations can be modified in the same way.

Fig. 1 shows the momentary registration of the operating state of a conveyor system, which appears on the screen output unit of the process video system.

In the lower half of the screen, the schematic plotting of the belt conveyor system is shown with loading state along the conveyor route, as well as the arrangement and length of the TT intermediate drives. In this example, one head drive with one motor unit and four driving belts each with three motor units are included. The diagram in the center of the screen shows the belt tension curve, the diagram above it shows the drive outputs.

Fig. 1: Display of the calculated belt tension curve and performance requirement of a belt conveyor system with four TT intermediate drives, using the process video system.



3. Loading and Unloading States

The system is in a steady state condition with nominal load uniformly distributed over the belts. In this operating state, which is inadequate for plant dimensioning, the wellknown saw-tooth plotting for belt tension (compare Fig. 1) results. As can be seen in Fig. 2, the belt tensions increase for instance when operating the conveyor when it is being fed with material, to more than nominal value, although only about 50 % of the nominal material load is being transported in this case.

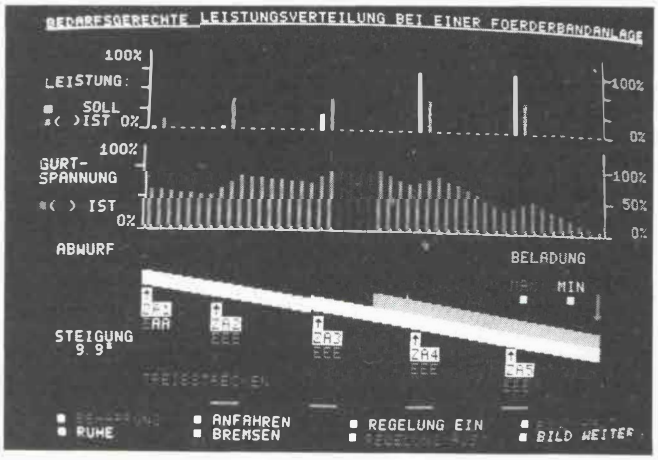


Fig. 2: Belt tension plotting and power requirement of a belt conveyor when operating when it is being fed with material during the steady state condition.

This effect arises because the total rating distributes uniformly over all drives along the conveyor route by the synchronization of the carrying belt, whilst the resistance forces of the plant vary due to unequal loading in the individual sections. The driving force transmitted by head pulley drive ZA 1 and intermediate drives ZA 2 und ZA 3 is only required on their associated conveyor sections without material load to very little extent, so that the belt tensions build up. In the loaded section of the plant the belt tensions decrease again in accordance with the resistance forces, whereby the output of the intermediate drives ZA 4 and ZA 5 is not sufficient to cover the requirement in the respective associated sections, so that the power deficiency is compensated for by the head drive and intermediate drives ZA 2 and ZA 3. This is illustrated in the upper diagram (Fig. 2) which displays the actual value and theoretical value for each drive output, for covering the resistance forces in the individual sections.

For correct dimensioning of the belt conveyor system, the load case shown in Fig. 3 also has to be investigated, which for instance occurs when the conveyor is operated without material load.

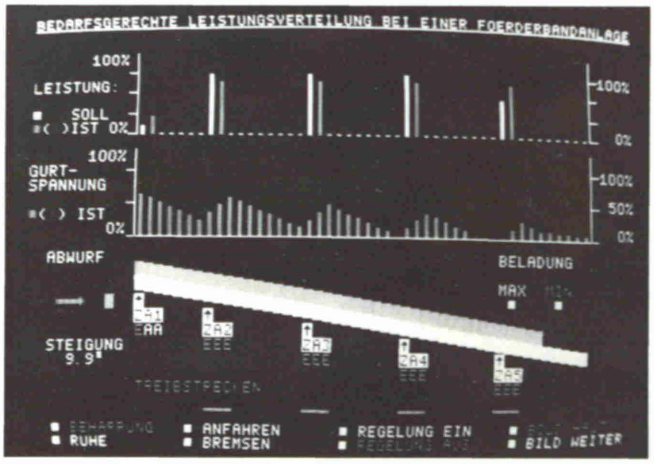


Fig. 3: Belt tension curve and power requirement of a belt conveyor when operating without material load during the steady state condition.

The associated section of the fourth intermediate drive has no material load here, whereby the motors have more output for the above reasons than would actually be necessary for this section. This can result in such a low belt tension ahead of the TT stretch that the carrying belt has excessive sag. By correctly adjusting the takeup tension of the carrying belt, which of course leads to a higher degree of belt tension, these handling conditions, which could cause breaks in operation, are avoided. Undue belt tension can arise to a much greater extent in the case of inadequate dimensioning during start-up of the plant if the load is not uniformly distributed. (Figs. 4 and 5)

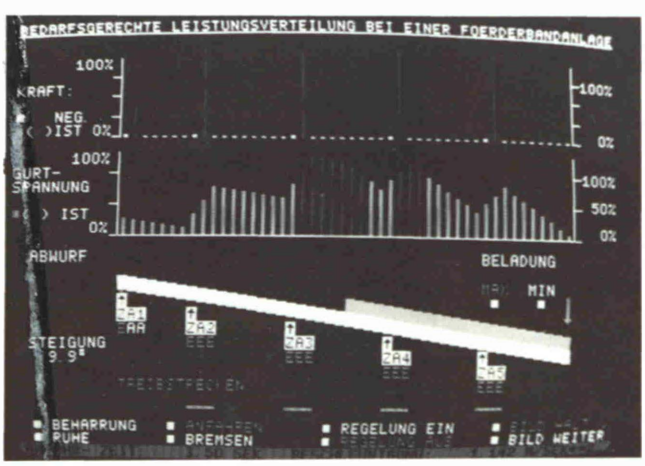


Fig. 4: Belt tension plotting of a conveyor on start-up when only partly loaded (50 % of the conveyor length loaded).

For minimizing belt tension forces arising along the conveyor in all loading and operating states, the drives can be

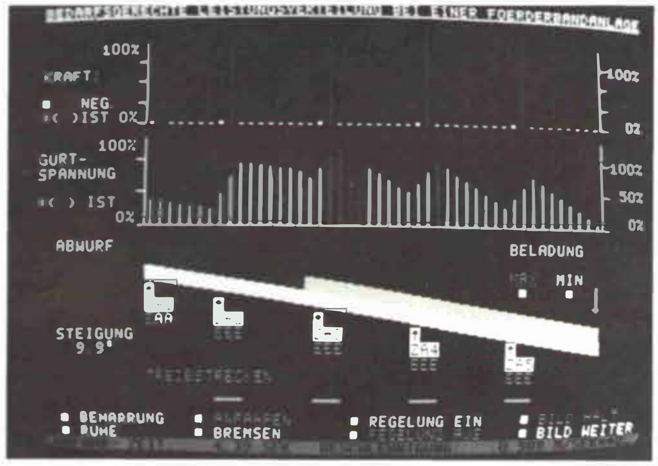


Fig. 5: Belt tension plotting of a conveyor on start-up when only partly loaded (65 % of the conveyor length loaded).

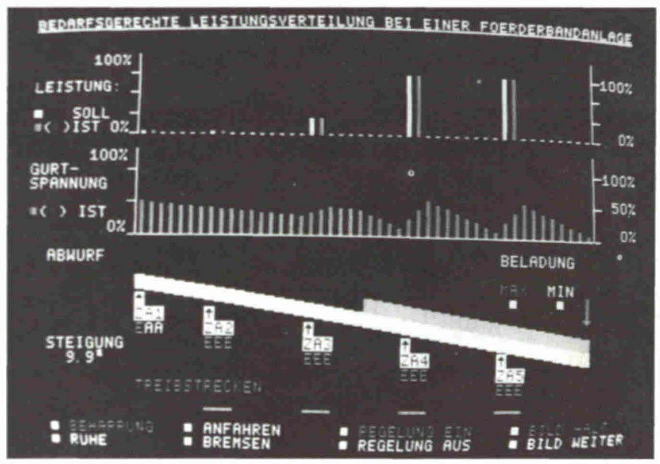


Fig. 6: Belt tension plotting and load-dependent power distribution of a belt conveyor with controlled drives (compare Fig. 2).

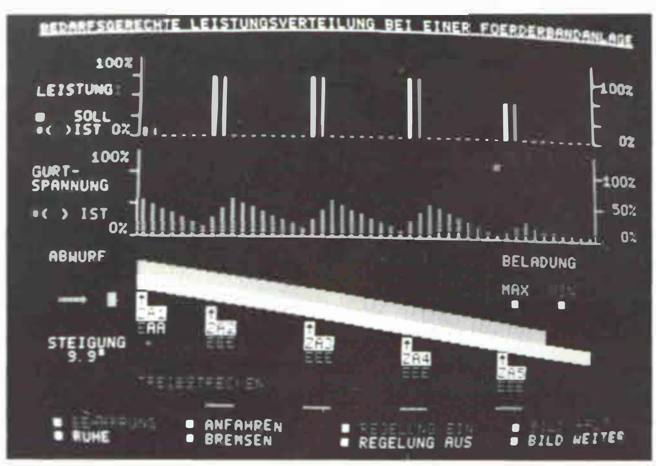


Fig. 7: Belt tension plotting and load-dependent power distribution of a belt conveyor with controlled drives (compare Fig. 3).

influenced in such a way in accordance with a suitable control strategy that each drive transmits sufficient power necessary for the respective section, corresponding to the momentary loading state. In this case, the theoretical and actual ratings of the individual drive units are equal, with a view to power requirements and power transmitted (Figs. 6 and 7).

In addition, any irregularities in the power output of the intermediate drives can be balanced out in a simple way with controlled drive units. However, with adequate dimensioning of the conveyor belt, the application of controlled drives is not absolutely necessary in the case of TT intermediate drives. The decision as to whether controlled and non-controlled drives are to be used only depends on a certain stipulated plant configuration based on a profitability calculation.

For the best possible design of a conveyor with TT intermediate drives, apart from operation with and without load, further partly-loaded states have to be investigated. A theoretically-possible distribution of material is indicated in Fig. 8.

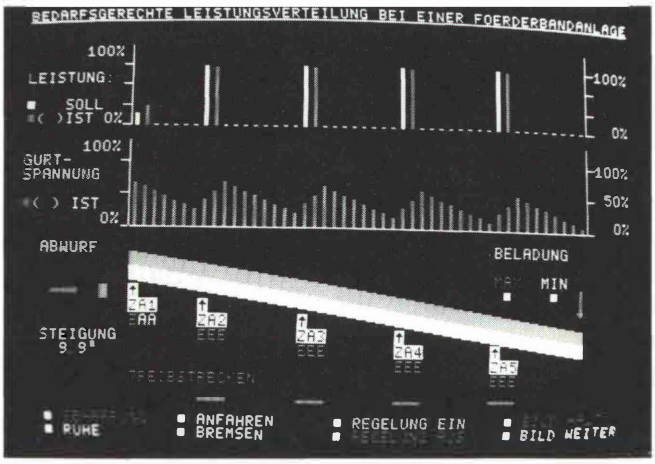


Fig. 8: Breaks in loading over the driving belts of the conveyor.

This shows the conveyor with nominal load up to the driving belts. Even with such an unfavourable loading state, the plant must run regardless of operating state. With proper selection of the driving belt lengths and arrangement of the intermediate drives along the conveyor route, best possible operation of the conveyor system is ensured after checking very many handling states with the aid of the computer.

4. Applications of the Simulation Computer Program

Possible operational breakdowns, such as failure of a drive unit can be simulated on the PVS and their effect assessed. In this way, there is a possibility of continuing safe operation of the conveyor thus increasing its availability, as a result of previously tried and tested emergency strategies.

In practice, the simulation computer program has already been applied successfully.

When breakdowns occurred in an extensible underground mine conveyor, which has reached about 70 % of its final length and which was equipped with three TT intermediate drives, the plant was subsequently optimized with the aid of the digital simulation involving minimum work expenditure for the necessary conversion. For the planned final length of approx. 1,500 m, a fourth intermediate drive had to be installed in the end whose suitable positioning was determined for the conveyor lengthening phases. Without further unforeseen breaks in operation, a handling rate of approx. 900 t/h coal was ensured with a belt speed of 2.5 m/sec and a fabric belt of 630 N/mm.

Apart from optimizing belt conveyors already operating with TT intermediate drives, the simulation program serves principally for planning such equipment.

In the coal mining industry recently one of the largest conveyors for underground mining was designed with a TT intermediate drive for handling 1,700 t/h coal, whose commissioning is scheduled for 1984. In order to overcome the difference in elevation of about 350 m, the belt conveyor which is 1,280 m long requires four drive units with 560 kW rating each, of which two units are each installed on the double-pulley head drive and on the driving flight of 400 m length.

Much experience has already been gained in 1978 with stationary belt conveyors having an intermediate drive. An inclined conveyor with a rise of 170 m and a length of 720 m is driven by a head drive with 4 × 80 m for handling 950 t/h coal, together with a TT intermediate drive 200 m long with 3 × 80 kW. The engineering work has been carried out for further planned belt conveyors with several intermediate drives.

5. Horizontal Curves

For realization of a conveyor route without transfer points over long distances, it is inevitable in some circumstances that belt conveyors not only have to be laid in vertical curves but also in horizontal curves. The application of such snaking conveyors is not unknown [4, 5]. The problem in this design is reliable belt tracking in the curve, since a radial force component is produced in proportional dependence of the belt tension forces, which favours the tendency of the belt to offtrack towards the inner curve side.

To stabilize belt tracking, without the introduction of forced guiding, counterforces must be applied which counteract the radial force. The counterforces are mainly effected by forward tilting of the carrying idlers and by cambering the idler supports. The necessary degree of these forces, directed towards the outer curve side, decisively depends on the belt tension. By installing an intermediate drive ahead of the curve of the conveyor, the belt tension can be reduced at that spot so that there is a low belt tension in the curve [6]. The radial force directed towards the inner curve side can thus be reduced, independent of the location of the curve, to a level which ensures safe belt tracking even if the curve radius is small. The complex connections which reflect the balanced position of the belt in the curve with different loading and operating states, particularly considering the application of a TT intermediate drive, lead to a simulation program with which numerous possible solutions for a definite project can be examined in a short period.

Fig. 9 is a belt conveyor, shown as a schematic using the PVS, which has a horizontal curve of approx. 700 m length about half way along.

An intermediate drive is positioned ahead of the curve so that the direction of flow can be changed by 65° with a curve radius of 630 m. In the center of the figure, the belt tension plotting is shown along the conveyor route with the position of the horizontal curve. The top half shows the cross-section through an idler support with belt positioning in the curve. Depending on the differing belt tensions, the belt positioning changing with constant set curve parameters can be calculated and displayed at all points of the curved stretch. The use of an intermediate drive ahead of a curve ensures safe belt tracking with minimum curve radii and little expenditure

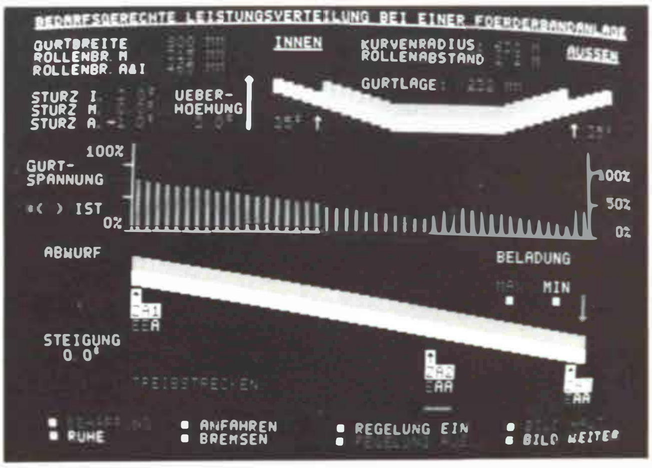


Fig. 9: PVS display and calculation of the belt tension and belt positioning on a conveyor in a horizontal curve.

with respect to the carrying idler settings necessary for steady belt positioning.

Figs. 10 and 11 show the various belt positionings, calculated and displayed by process video system, on the idler supports with varying load states.

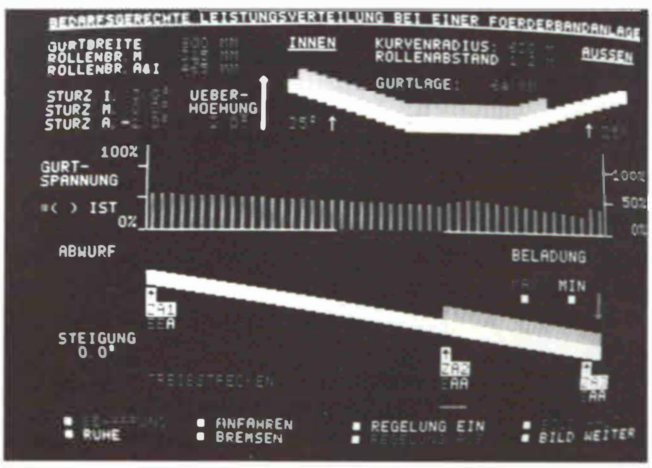


Fig. 10: Belt positioning on an unloaded curve, calculated and displayed by PVS

For minimizing belt tracking measures or belt off-tracking, an adjusting strategy can also be considered which influences the output of the intermediate drive to such an extent that an almost constant belt tension plotting is gained along the

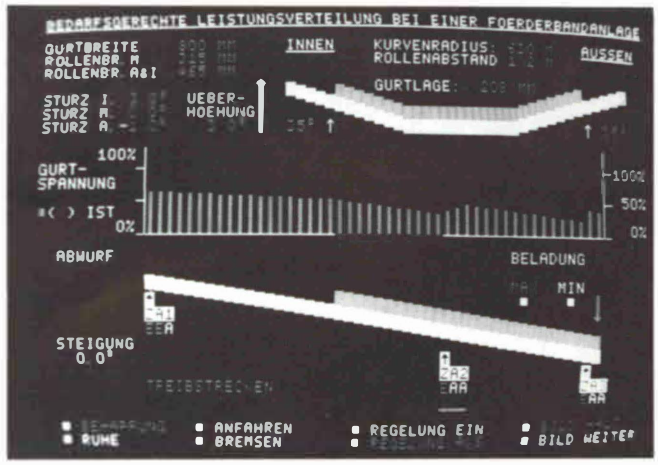


Fig. 11: Belt positioning on a loaded curve, calculated and displayed by PVS

curve stretch with changing operating and loading states. The process video system offers the possibility here, for a definite project, of finding the best solution, technically as well as economically.

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