DO BELT CONVEYOR STANDARDS REPLACE FUNDAMENTAL PRINCIPLES ?

(K-P. MULLER, PHB WESERHUTTE (S.A.) (PTY) LIMITED)

INTRODUCTION

Belt conveyor standards are essential and serve to maintain universally acceptable minimum guide lines for the design criteria.
However, occassionally some belt systems do not meet with the design engineer's or end user's expectations.
The object of this paper is to outline in a simplistic presentation the fundamental behaviour of belt systems. In many instances an over-simplified explanation of the system is illustrated in order to highlight the basics.

The paper will also address some areas of conveyor systems which are not covered in great depth by the standards.

We will conclude with case histories which illustrate conveyor installations that included fundamental problems inherent in the system. We also discuss systems which have been modified without a sound understanding of the original design philosophy. The result being to convert a satisfactory conveyor system into an unacceptable "problem" conveyor

COMMENTS ON AVAILABLE STANDARDS

Numerous standards for belt conveyor components are readily available. For belt conveyor systems comprehensive standards are very helpful, covering the basic design requirements relating to:

- volumetric flow and mass flow
- resistance to motion
- power requirements
- design and layout of drive systems
- belt traction forces
- belt tensile forces
- design and layout of belt conveyors
- minimum pulley diameters
- layout of transition curves

Additional required design data is complemented in various belt manufacturer's handbooks. Calculations and recommendations are tabled relating to concave/convex curves, permissable belt deflections, life cycles, etc.

The manufacturers' method of calculation however, may differ considerably in their mathematical approach, but the end results are similar.

The most widely acceptable standard in SA is ISO 5048. This is an easily applied standard for power calculations, possibly on the conservative side resulting in a degree of reserve power. But, this standard has proven successful in numerous conveyor applications world wide.

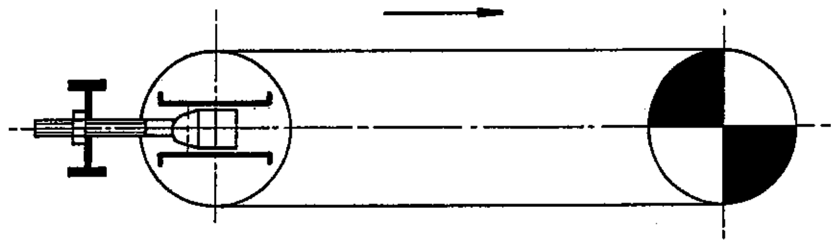
With the available standards and recommendations a majority of belt conveyor systems may be designed without the use of advanced computer technology. What is required however, is the understanding of the basic principles of conveyor behaviour and the correct application and interpretation of the calculated results.

One area of conveyor systems that frequently give rise to problems is associated with take-up systems.

Unfortunately the above mentioned standards do not cover in great depth the alternative methods of take-up system.

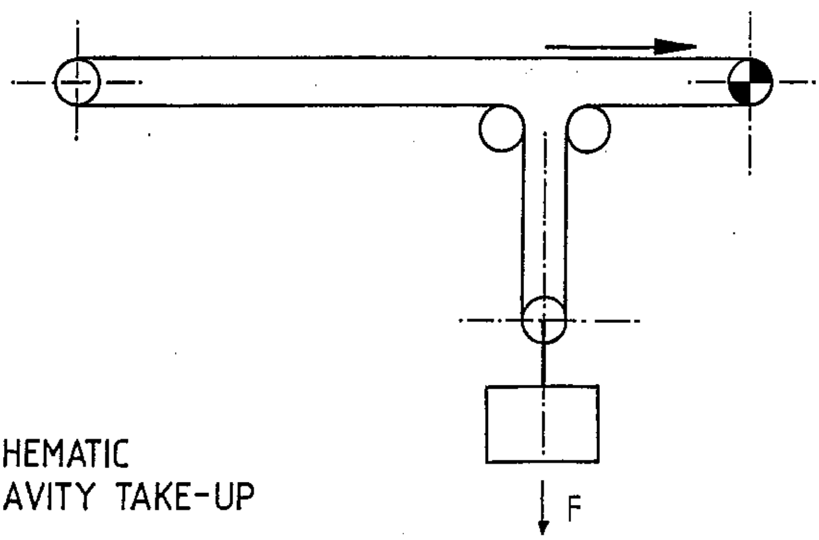
At this stage we will cover the basic principles of various configurations.

The screw-type take up is a proven and popular arrangement, but the system is limited to relatively short conveyors.



TYPICAL ARRANGEMENT OF SCREW-TYPE TAKE-UP

On longer conveyors perhaps the most common take-up system is the gravity take-up device. However, with the developments of long, high-capacity conveyor systems, even gravity take-ups have their limitations. This has led to the introduction of automatic power take-up systems.



SCHEMATIC
GRAVITY TAKE-UP

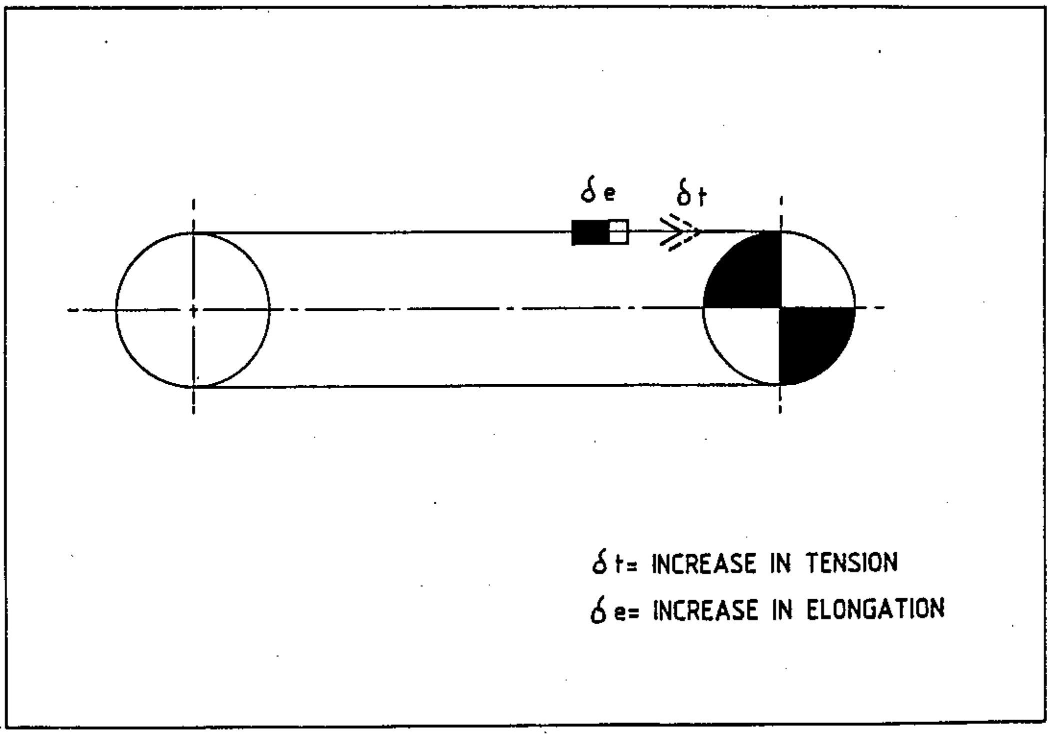
SIMPLIFIED BEHAVIOUR DURING START-UP

To illustrate the behaviour of a conveyor during starting let us consider a conveyor with a starting time of 20 sec.
What is happening from the time the drive motor is energised to the time the conveyor attains full speed?

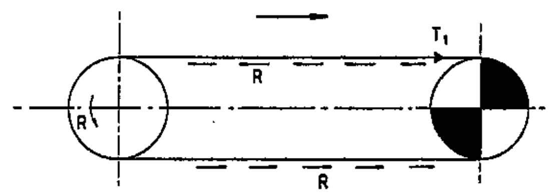
1. The belt speed increases from zero to full speed.
2. The power increases from zero to full power.

Can we now conclude that during the starting time of 20 secs the belt is progressively stretching from zero to maximum elongation?
Let us examine what is actually taking place during this time.

It is a fact that the power increases from zero to maximum as the conveyor attains full speed, but the torque remains more or less constant. The torque from the drive pulley induces a tension into the belt. Since the belt is an elastic element this tension results in an elongation of the belt following Hook's law.



On energising the drive motor the torque at the drive pulley will increase the tension in the belt until this tension equals the total resistance of the system. At this point the belt will begin to move. To maintain belt movement will not require any further increase in tension,

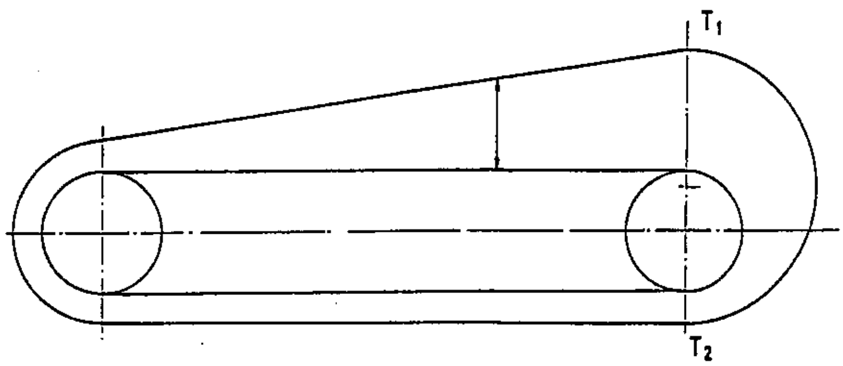


WHEN $T_1 = \Sigma R$ THE BELT WILL BEGIN TO MOVE

since no additional resistances to motion have to be overcome. In fact, there will be a slight decrease in tension since the break-away forces have been overcome.

Since the elongation of the belt is directly proportional to the tension in the belt, the extension of the belt is progressively generated as the drive pulley torque increases from zero to maximum. At this point the belt begins to move.

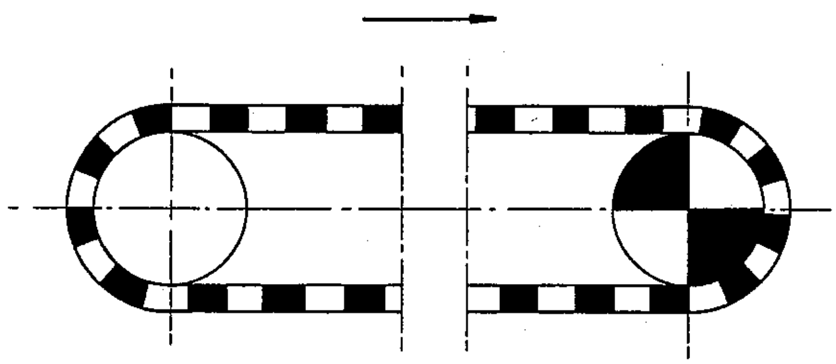
BELT TENSION AT POINT



This is clearly illustrated by the behaviour of a gravity take-up system, where it will be observed that upon energising of the drive motor the counterweight will almost immediately drop a distance to absorb the initial stretch of the belt. It will remain in this new position until the belt attains full speed. At this point it may be noticed that the counterweight will raise slightly. The raising is due to the fact that the tension in the belt required to accelerate the system is no longer required.

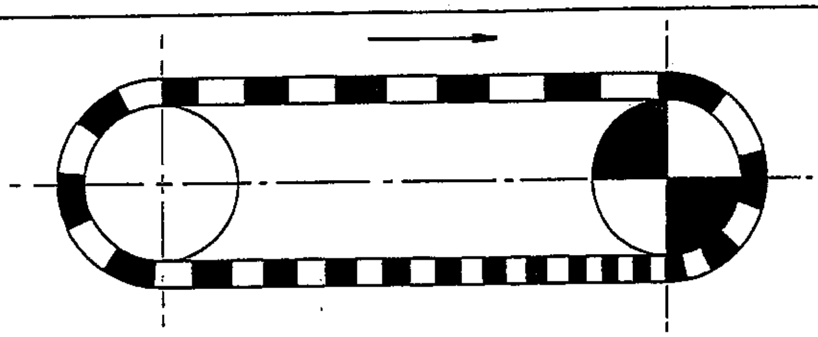
SIMPLIFIED BEHAVIOUR OF THE BELT WITH A SCREW TAKE-UP

Consider now a screw take-up system where the length of the belt is constant during all conditions including starting and stopping. Where is the belt stretch absorbed?



STATIONARY BELT
EQUAL BELT STRAIN DISTRIBUTION AROUND THE SYSTEM

Looking at a simple head driven horizontal conveyor it will be understood that in the running condition the tension on the return side is low. From the tail pulley to the head pulley the tension increases to a maximum. As the conveyor stops the tension around the system will equalise, i.e. the tension on the return strand will increase and the maximum tension at the head end will decrease. The tension now in the belt is equal to the average running tension. The total length of the belt remains constant.



RUNNING BELT
CHANGE OF BELT STRAIN DISTRIBUTION AROUND THE SYSTEM

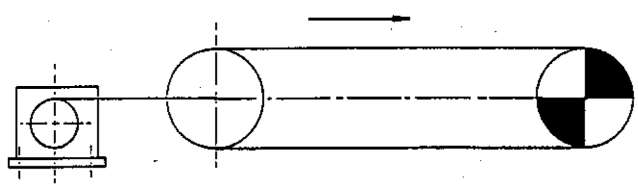
The function of the screw-type take-up is to pre-stretch the belt such, that the tension in the belt is equal to the calculated average tension required for the system.

As mentioned previously, maximum tension occurs at the point of break-away. Maximum torque induces maximum belt tension causing maximum belt stretch. The stretch of the belt commences at the head and decreases progressively to the tail. The degree of stretch is compensated by the contraction of the belt on the return side.

On larger conveyors it is impractical to incorporate a screw take-up Since the forces required on the screw become too large, resulting in a cumbersome arrangement and the take-up distances become too great.

SIMPLIFIED BEHAVOUR OF THE BELT WITH A POWER TAKE-UP

On long, high-capacity belt conveyors however, the same principles can be applied. The screw take-up is replaced by a power operated winch. This system, often referred to as "Rheinbraun" system, is operating very successfully. Essentially, this is a motorised winch with a calculated preset tension, the only adjustments made by the system are automatic and compensate for changes determined by ambient conditions.



POWER TAKE-UP SCHEMATIC

An alternative method of automatic power take-up winches is the "controlled" take-up winch.

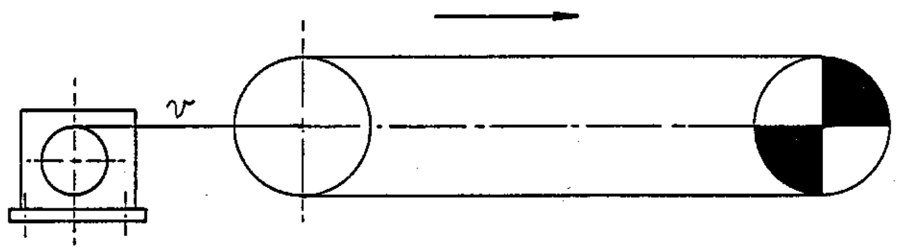
The principle of this system is to reposition the take-up carriage during starting to compensate for the stretch of the belt.

Let us consider the case of a total power failure occuring during the belt conveyor running condition. The belt will cruise to a halt, remember, with no power available to move the take-up carriage to relax the belt. The system is now identical to the "Rheinbraun" system mentioned earlier, i.e. tensions are equalising around the system, this may result in a large increase in tension on the low tension side of the belt.

Provided the components in the low tension area, for example take-up pulley, snub pulley and supporting structures are designed to take this increased tension, trouble-free operation will ensue. If, on the other hand, components are not originally designed to allow for these increased forces, then precautions are necessary to avoid the occurrance of increased tension at the low tension side.

Controlled "Low Tension" System

A "low tension" take-up system is characterised by a rapid response to changes in belt tensions. The travel of the take-up pulley has to keep abreast with the initial stretching of the belt. An important feature is the incorporation of a mechanical or hydraulic tension (torque) limiter to allow the winch, in case of a power failure, to slip. This will permit the take-up carriage to relax the tension in the system.



CONTROLLED "LOW TENSION" WINCH V >10m/min
TORQUE LIMITING DEVICE

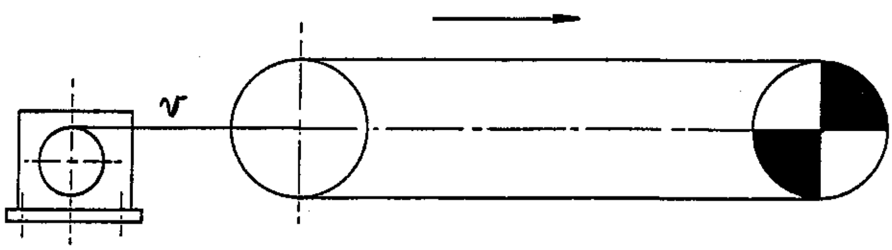
<u>Controlled "High Tension" System</u>

The feature of the high tension take-up system is the pre-tensioning of the belt system prior to starting. When the belt has achieved its full speed, i.e. the acceleration component is no longer required, the winch is allowed to partially relax the belt.

This arrangement is commonly used in systems where an increased factor of safety during running is desired, alternatively, where a decreased factor of safety is acceptable during start-up.

With a grasp of the above take-up philosophies common failures and shortcomings on belt conveyor systems may be avoided.

The following brief case histories will highlight the above outlined importance of belt take-ups:

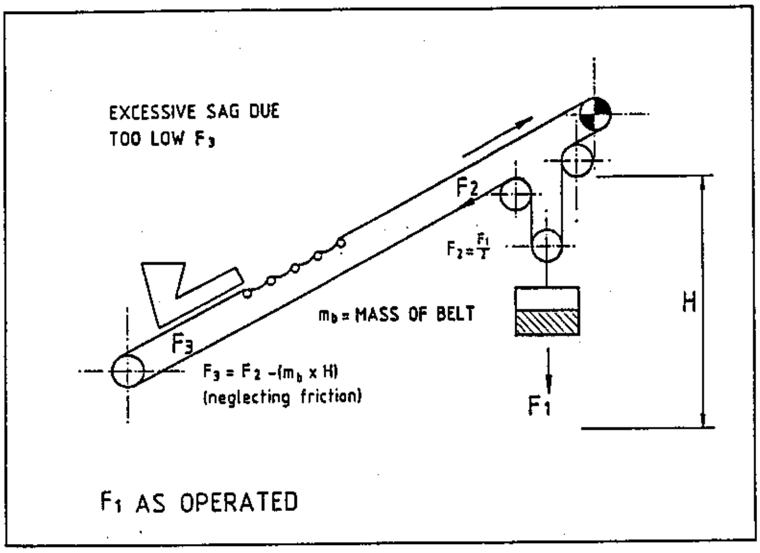


CONTROLLED "HIGH TENSION" WINCH V < 3m/min

CASE I

INSTALLATION

A high capacity, inclined belt conveyor system with head drive station incorporating scoop controlled couplings and a gravity take-up system.



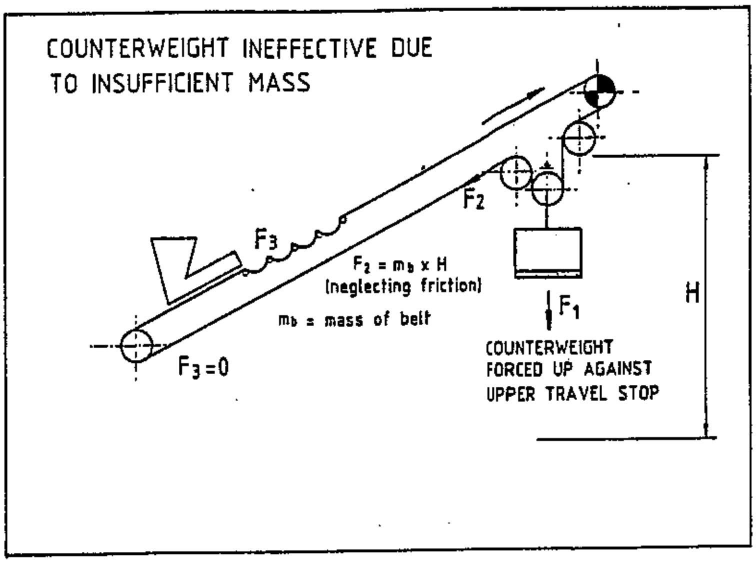
PROBLEM

Numerous splice failures resulting in low plant availability.

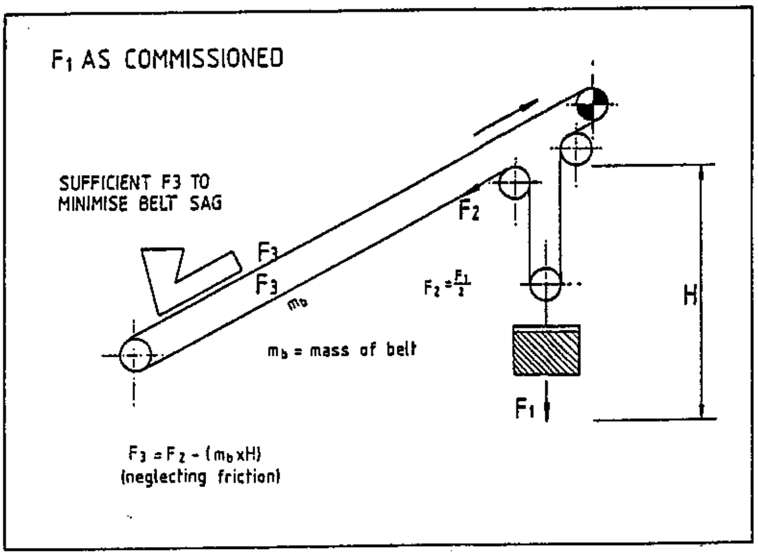
OBSERVATION

1. The fully loaded belt accelerates to full speed in 5 seconds.

2. No movement of the counterweight during starting and stopping of the belt.



3. Extreme low tension at the tail end evident by the enormous belt deflection.



EXPLANATION

The extreme high acceleration, coupled with an excessive belt sag at the tail end results in enormously high transient forces in this area.
If a belt splice happens to be in this area, then the splice is subject to forces for which it was not designed, leading to premature failure.
The deterioration of the scoop control led to uncontrolled acceleration. This initiated a history of splice failures. It was assumed that by reducing the counterweight mass the tension in the system will also be reduced thus alleviating the problem.
However, the consequence of reducing the counterweight mass in fact increased the belt sag at the tail end. This led to a multiplication of the belt transient forces during start-up. This increased the frequency of splice failures.

CORRECTIVE ACTION TAKEN

1. Counterweight was re-instated to its original mass.
2. The scoop control was recommissioned to its original specifications.

RESULTS

Frequent splice failure problems eliminated this leading to a higher plant availability factor.

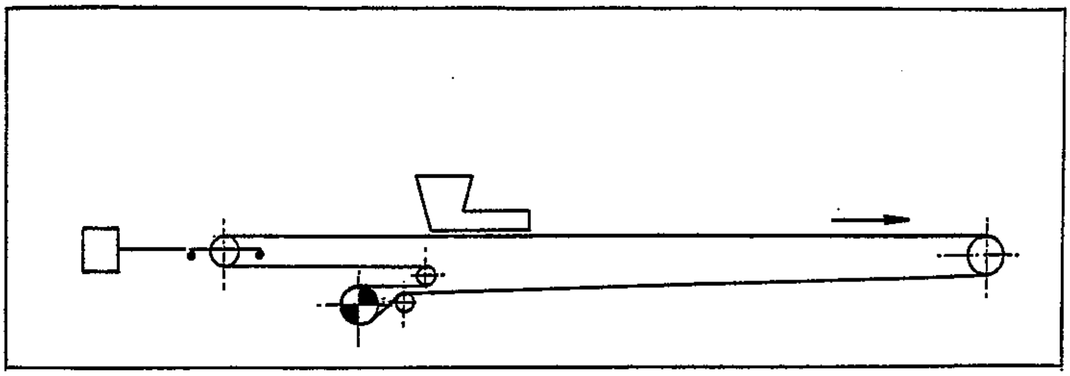
COMMENTS

This is an example of how a correctly designed and installed system was subsequently changed on site, creating operational problems due to lack of appreciation for the original design concept.

CASE II

INSTALLATION

Overland, high capacity, high speed tail driven conveyor, slip ring motor resistor controlled, incorporating a power operated winch take-up system.



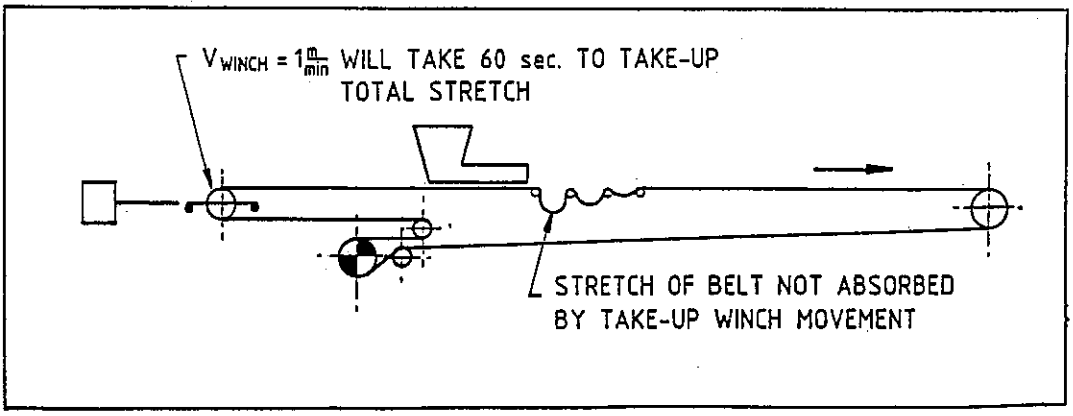
PROBLEMS

Excessive slipping of drive pulley even under no load.

Inability to start a fully loaded conveyor .

OBSERVATION

1. Excessive sag of the loaded portion of the belt at the tail end during starting.
2. Violent oscillations in the take-up winch tension during starting, coupled with low tension values.
3. Inability to start under full load.

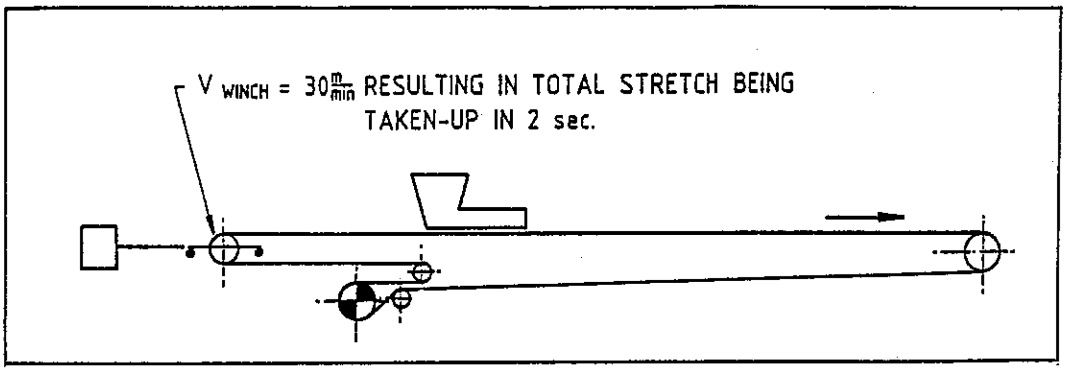


EXPLANATION

The movement of the take-up trolley was too slow to absorb the stretch of the belt and maintain the required tension in the system. The severe loss of tension explains the excessive squealing and slipping of the drives during starting and the excessive loaded belt deflections.

CORRECTIVE ACTION TAKEN

The original slow speed winch was replaced with a suitable high speed hydraulic unit in order to maintain the required T2 tension under all conditions.



RESULTS

The belt system is now capable of starting under all load conditions without slippage.

COMMENTS

This is an example of a system designed without taking full cognisance of what is required of the take-up system during starting.

The hydraulic winch unit incorporated large accumulators to improve the response speed of the winch.

The components in the take-up area were not designed for high tension forces. To safeguard these components the maximum tension generated by the winch was limited by the use of pressure relief valves even in the event of a total power failure.

CASE 3

INSTALLATION

An overland, tail driven horizontal conveyor system incorporating fluid coupling drives and a "low tension" automatic controlled electric winch take-up system.

PROBLEM

1 Excessive slipping during starting.

2 Excessive belt lift

3. Mechanical failure of pulley shaft bearings in the take-up area.

OBSERVATION

The installation incorporated a fast reacting, torque limiting "low tension" take-up system which as originally commissioned functioned without problems unfortunately without regard for the original control philosopy or the take-up system. This neglect of oversight led inevitably to the above problems.

CORRECTIVE ACTION

Re-instate the original winch control philosophy into the new PLC.

RESULTS

The system now operates satisfactorily as originally designed and commissioned.

COMMENTS

This is an example of how the control of a correctly designed and installed system had been modified without reference to the original philosophy which led to the above problems.

CONCLUSION

Standards are essential. Additionally, a sound understanding of belt conveyor principles is imperative to achieve an efficient installation. For the majority of conveyors the available standards give a straight forward approach to the design calculations.

In depth dynamic analyses may be required on more complex installations such as:

long, multiple drive conveyors

horizontal curved conveyors

conveyors with high speeds and accelerations

Careful design consideration to all aspects of a system, including the take-up device, will be rewarded by a reliable installation.

We ask again the question: Do belt conveyors standards replace fundamental principles?

The answer to this question must be an unqualified NO!. Belt conveyor standards complement, (not replace) fundamental principles.

It must be appreciated that a conveyor system comprises of mechanical, electrical and control devices. An ideal conveyor system is a harmonious interaction between all the components and therefore a change in any one of these can upset the total balance of the system.

Conveyors are basically simple - people make them complicated.