FLYWHEELS, BRAKES AND OTHER DEVICES

By: M.Otrebski

1.0 INTRODUCTION

Over the years the control of conveyors has become more demanding and complex. Conveyors are getting longer and carry higher capacities whilst simultaneously we are given access to more sophisticated design tools and improved hardware which allow both better evaluation of conveyor behaviour and the application of most complex concepts.

It is no longer exceptional to find conveyors fitted with flywheels, brakes, sensors, special drive systems which include the means to aid conveyor control during start up, stopping and normal run.

2.0 EVOLUTION OF CONCEPTS

The current approach to the control of transient phases of conveyor operation is based on the understanding that any change of conveyor state must be as gradual as possible.

Alternatively it may be said that there are limits as to how fast any change can take place. The theoretical basis for this approach was developed in the early 70's and explained how such parameters as conveyor length, belt type and control parameters are linked into one coherent approach for the control of starting or stopping [1] - [8].

Prior to the idea of controlled start up or stop, the application was limited frequently due to hardware limitations, whilst a so called “soft start” device mostly defined a unit which allowed ease of electric motor start up and had limited positive influence on a conveyor.

3.0 FLYWHEELS AND BRAKES

Flywheels and brakes have been applied in conveyor design for a long time. It is, however, important to note that originally these two devices had to achieve two main goals ie. either increase or decrease the stopping time of a conveyor. These requirements were dictated by “outside” factors (chute capacities, stopping time of chain of conveyors, etc.) with little or no reference to the dynamics of a conveyor.

The flywheel, being a “self supporting” and reliable device, was well suited at the time for applications where conveyor control systems were mostly very basic. It has been carried over in that role when the need for much better and precise control has become apparent.

With the aid of sophisticated design tools, it was now possible to improve conveyor performance by simply manipulating the size of the flywheel. How belt tensions and velocity curves can be changed is illustrated by fig. 1 & 2.

Of note is the fact that the original design during stopping has been affected not only by very low tensions, but also the take up trolley had tendency to run out of travel and lock itself in the surrounding structure. By the introduction of the flywheels, tension and velocity patterns were improved and problems with the take up trolley eliminated.

These benefits cannot be underestimated.

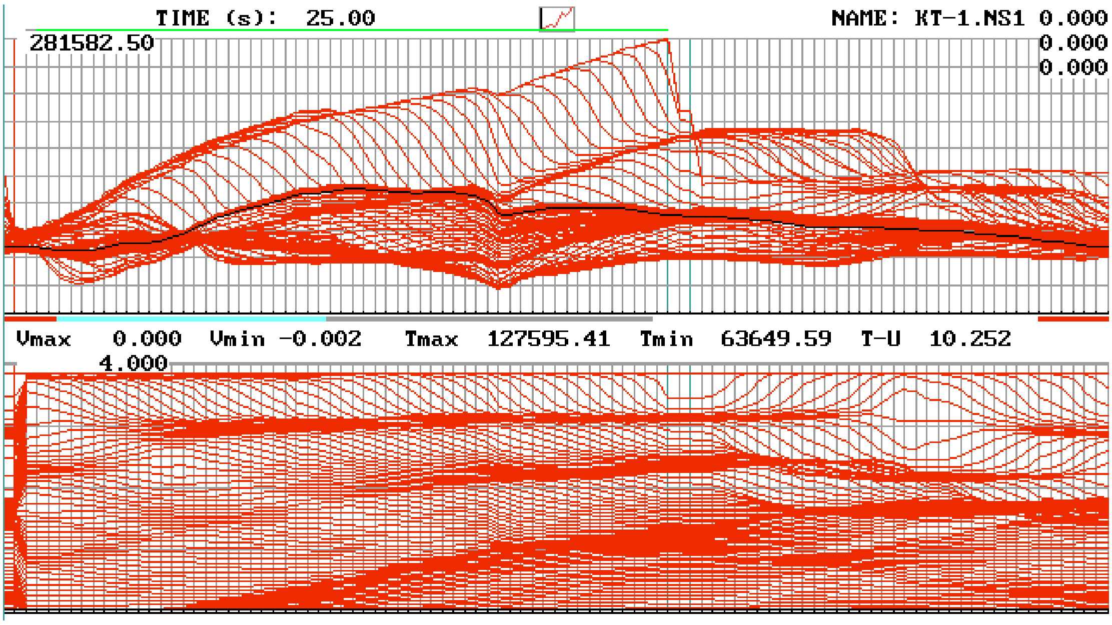

Figure 1: 7 km long overland conveyor. Loaded stop. No flywheels. Graphs of belt tension [N] (upper) and belt velocity [m/s] (lower) along the conveyor.

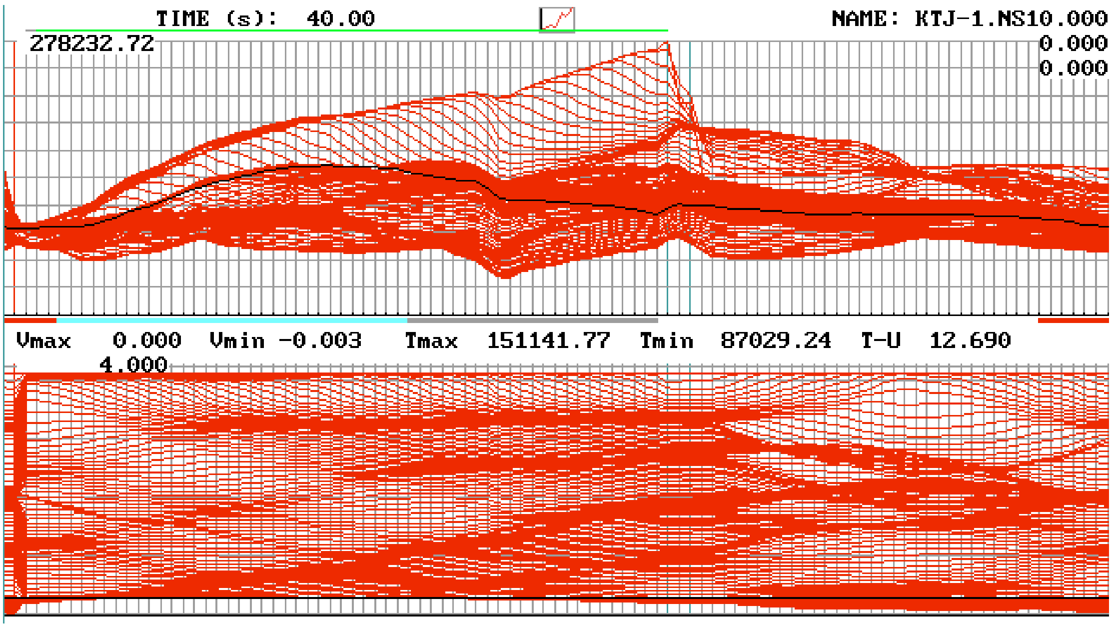

Figure 2: 7 km long overland conveyor. Loaded stop. Drives with flywheels. Graphs of belt tension [N] (upper) and belt velocity [m/s] (lower) along the conveyor.

However, from time to time caution is advised.

Attached figure 3 shows an interesting case of a short high powered, high capacity inclined conveyor. Due to unsatisfactory stopping performance of the conveyor as indicated by initial analyses, the intention was to utilise the benefits of flywheels. Tests with progressively increased flywheel inertia were performed which showed two interesting things:

- stopping performance improved as inertia increased;
- oscillation of belt tension could be noted in the area of the drive station which were more pronounced with the increase of flywheel inertia.

These tension oscillations can be clearly seen on the upper part of the graph.

Closer investigation revealed that once the conveyor has stopped, the unrestrained flywheels still tend to move within the limits imposed by the system, leading in turn to the observed phenomena.

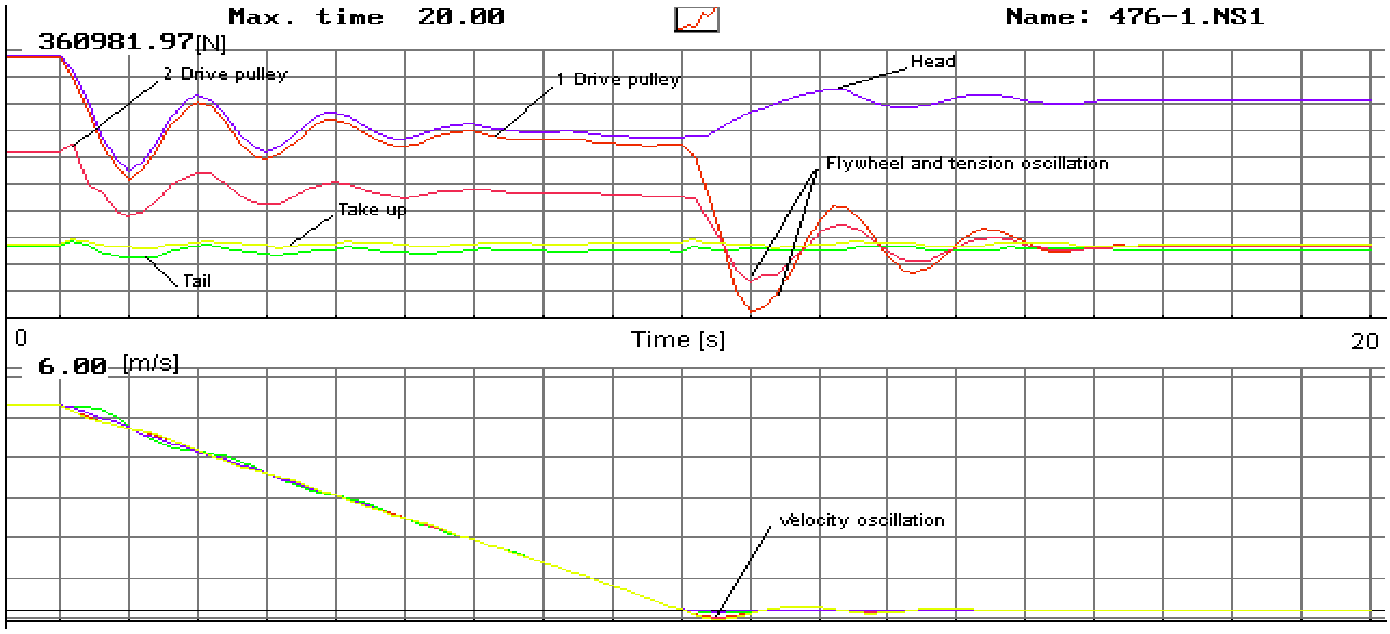

Figure 3: Fully loaded stop. Flywheels 6 x motor rotor inertia. Graphs of belt tension [N] and belt velocity [m/s] at specific points. Note drop of tension almost down to 0 [N] during initial phase of tension oscillations as a result of flywheels action once conveyor has stopped.

As the holdback was positioned at the head end, consideration was given to the introduction of small brakes which would dissipate flywheel energy without affecting stopping performance.

After taking into account all the pros and cons, flywheels and brakes were not used and other measures were introduced to achieve acceptable stopping parameters.

This case also indicates some initial contradiction of simultaneous application of both flywheels and brakes. What is frequently forgotten, especially in the case of relatively short conveyors, is that the influence of a flywheel is permanent and with decreased loads may lead to unacceptably long stopping times. A properly set and controlled brake will provide a stopping time within acceptable limits. In simple terms it may be stated that under high loads, stopping is controlled by flywheels. As the load decreases, brakes start playing a dominant part.

As mentioned earlier, a flywheel provides effective and reliable storage of energy. It is interesting to note that, to a degree, this fact may be used to improve conveyor start up performance.

This is less important in the case of very long conveyors but may be of practical application for shorter installations. It frequently happens that in such cases start up control is very basic and far from ideal.

The following figures 4 and 5 show the results of an investigation into a 500 m long, high powered, conveyor with 32 m lift at the head end. Value dF represents the difference in maximum and minimum tensions observed during start up.

Please apply to the IMHC for a copy of the 2 graphs.

- *Figure 4: Maximum tension difference dF as a function of Flywheel Size [No Load Condition]*
- *Figure 5: Maximum tension difference dF as a function of Flywheel Size [Full Load Condition]*

Two important observations can be made:

- the influence of the flywheel is not indefinite ie. beyond a certain flywheel size little improvement is seen;
- the no load condition benefits more than the loaded case.

The second of the two aspects is important, as in many instances partial or no load start up cases, are the source of major problems and may be rectified without major change to the conveyor set up.

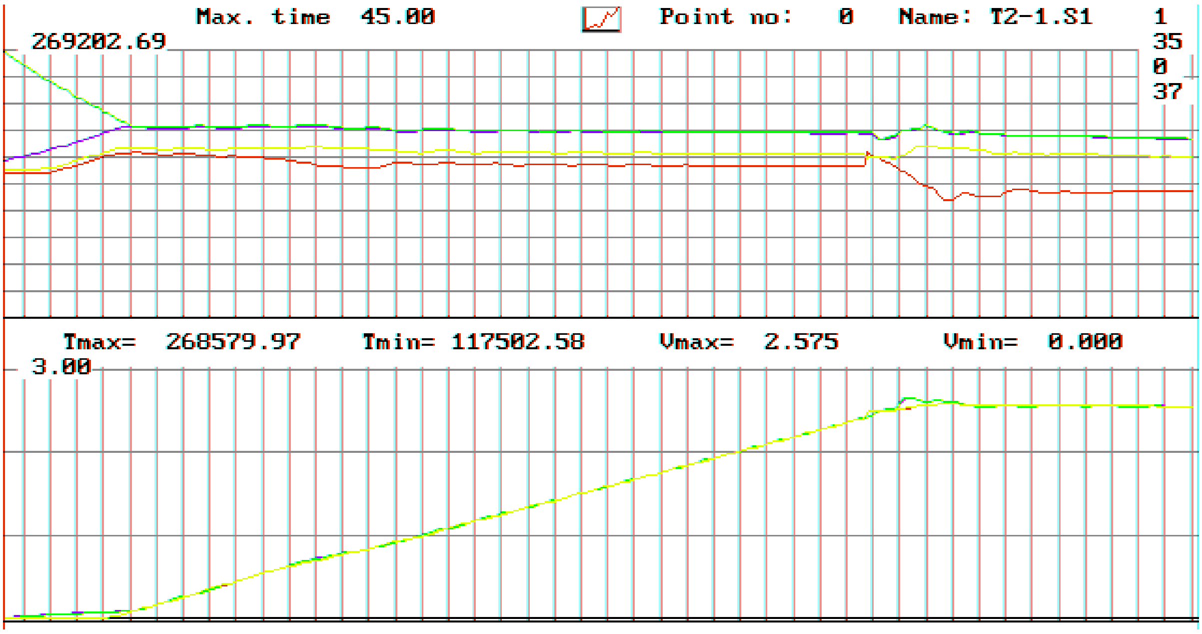

Figure 6: Full load, start up Graphs of belt tension [N] (upper) and belt velocity [m/s] (upper) at: tail pulley (green and blue) and drive pulley (red and pink). Note initial belt creep as a result of brake torque ramp down. Slight disturbance of belt tensions can be observed as a result of motor energising.

The role of brakes has been briefly mentioned earlier, but only as a device which aids stopping. On some occasions, brake may perform a start up control function.

One obvious case will be where a conveyor, at least from time to time, operates in regenerative mode.

Figure 6 is a good illustration of such a case. It represents regenerative start up of a 1,1 km long down hill conveyor.

It can be seen that as the brake is slowly released, the conveyor starts accelerating. As the conveyor has been built with a relatively simple drive system, the drive is energised very late as the speed approaches a nominal value. The same brake is also used for fully controlled deceleration.

A rather unusual application of a brake is shown by figure 7 and figure 8

An overland conveyor which was originally fitted with fixed volume fluid couplings suffered from poor start up performance. To rectify the situation, fully controlled brakes were installed on each drive. As motors are energised, the brakes are released over a period of time, counteracting torque developed by the fluid coupling. Notwithstanding all apparent drawbacks, the method was successful in its application.

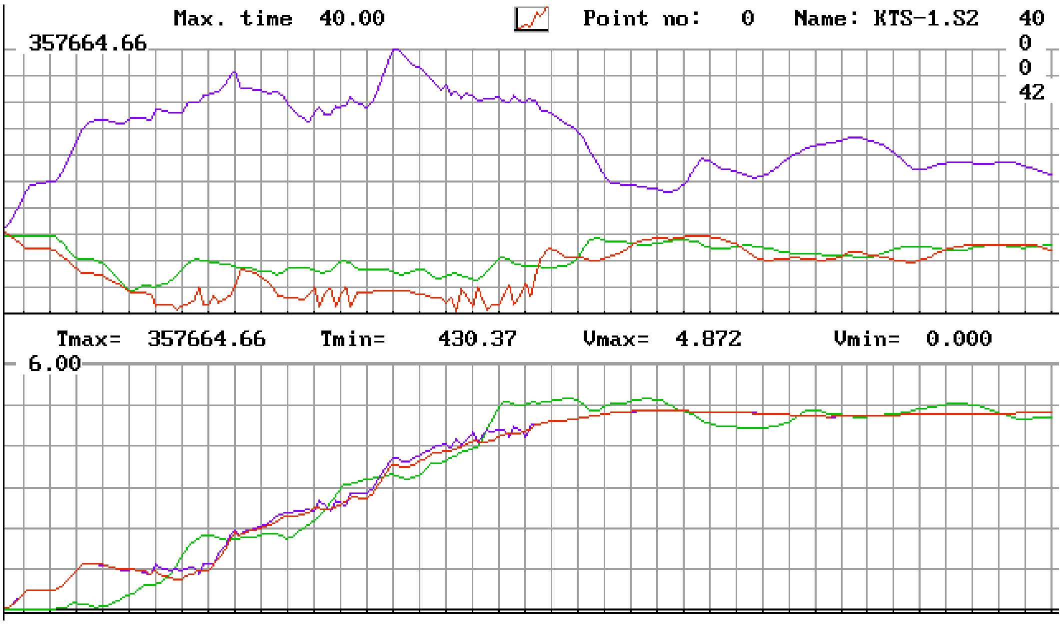

Figure 8: Overland conveyor. Full load start up. State before modification. Graphs of belt tension [N] (upper) and belt velocity [m/s] (lower) at: tail (green), head:T1 (blue) and T2 (red). Note low values of T2 tension and resulting from that drive pulley slip.

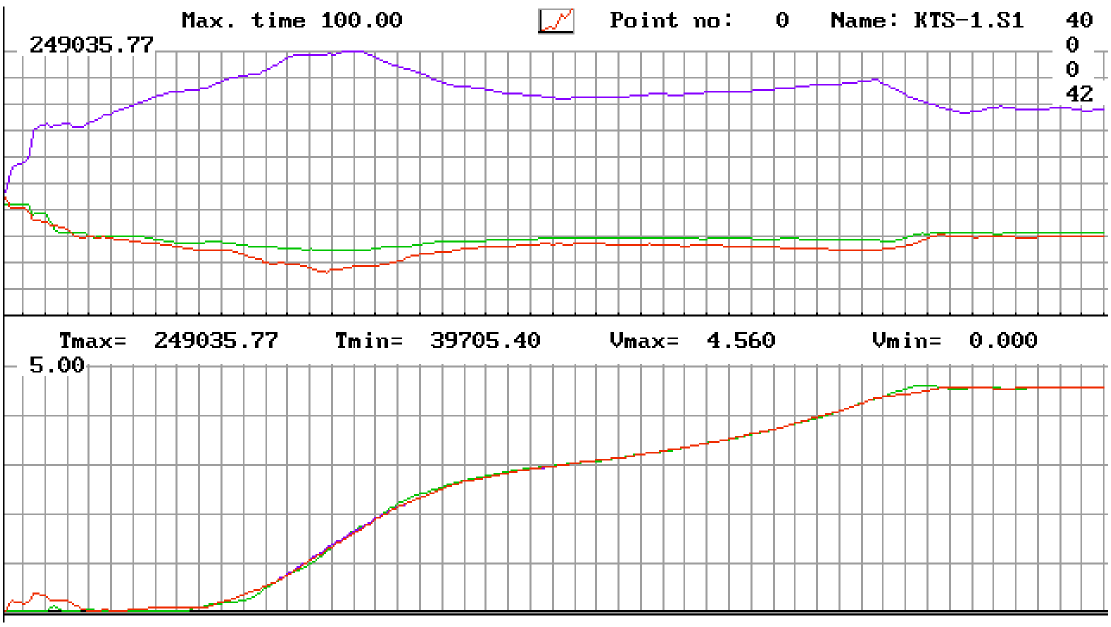

Figure 7: Overland conveyor. Full load start up. State after modification. Graphs of belt tension [N] (upper) and belt velocity [m/s] (lower) at: tail (green), head: T1 (blue) and T2 (red).

4.0 OTHER OPTIONS AVAILABLE

It is frequently found in practice that the choice of options in terms of control is limited. It has been found that operators try to avoid flywheels, and are not keen on the application of brakes. In addition, one is faced with limited changes which can be introduced. Whilst this may make the task of rectification or development more difficult, it is possible to apply other methods which will resolve at least some of the problems.

The case presented by figure 9 is similar to that described earlier and depicted by figure 1.

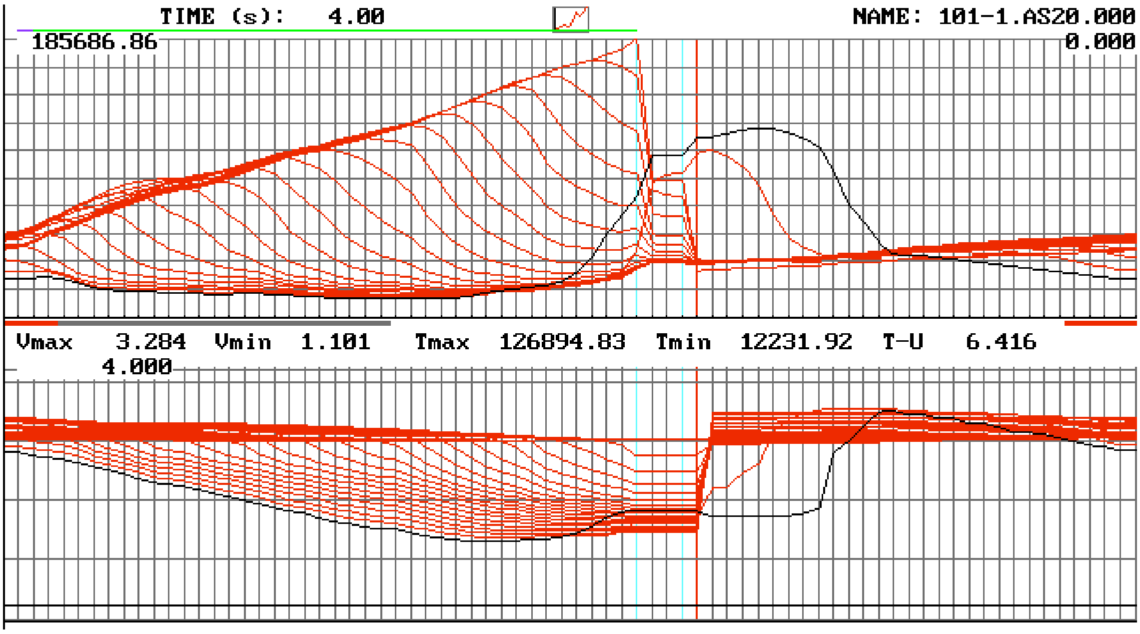

Figure 9: 2,6 km long conveyor. Aborted start up under full load. Original design. Graphs of belt tension [N] (upper) and belt velocity [m/s] (lower) along the conveyor. Note belt tension spike at take up location as a result of take up impact at the structure.

However, the solution which has been applied is different, although possibly less “elegant”.

As most of the equipment for the specific conveyor was already on order, the scope of possible modifications was rather limited. It was found that a capstan brake system attached to the take up would provide an effective and inexpensive solution. The system operates as a one way brake, ie. the take up is free to move in one direction (in this case it allows unobstructed belt tensioning) but restrains the take up movement in the opposite direction. Its effect may be compared to a gravity take up system with two take up masses which act depending on the take up trolley direction of movement.

Figure 10 shows the results for the conveyor after modification.

It may be noted that the belt tension and speed curves have not been improved as might have been the case with the application of a flywheel. However the source of major operational problems had been eliminated.

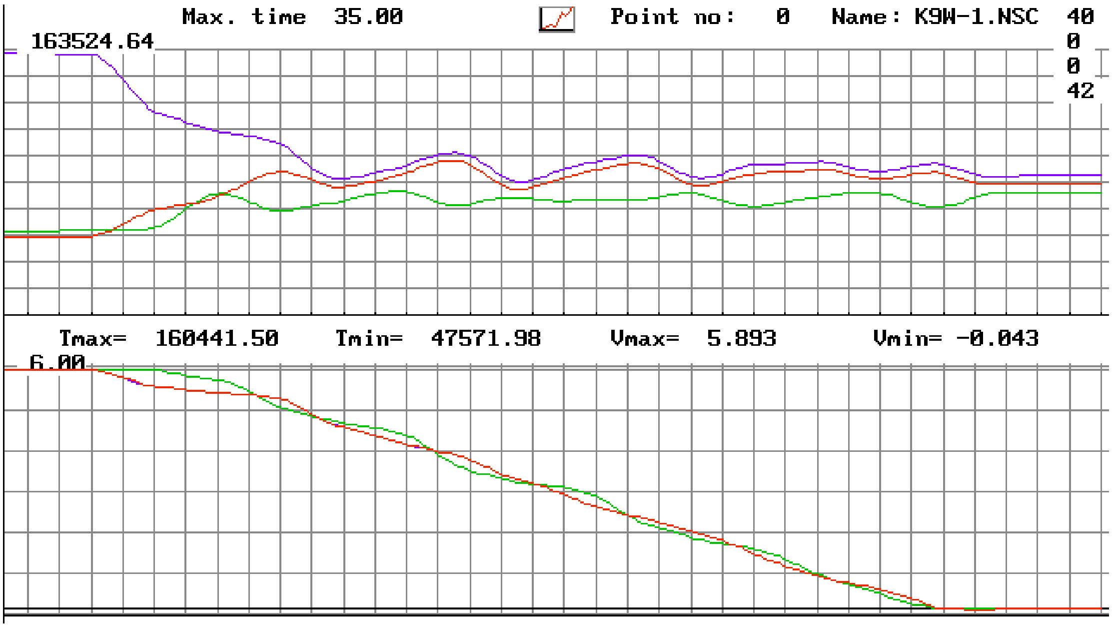

Figure 10

Frequently significant improvements can be achieved if the available equipment is utilised to its full potential. The case in point is the application of so called controlled stopping when a conveyor is fitted with either a variable fill fluid coupling or even a frequency inverter. The philosophy behind the concept is simple and in a way is the reverse of a conveyor controlled start up.

The moment the conveyor is to be stopped, instead of de - energising the motors, torque delivered to the drive pulley is decreased over a period of time. Where variable fill fluid couplings are used, this is done by the removal of oil from the working circuit over an extended period of time. The frequency invertor will perform that task by means of changing electrical parameters. As long as the time of motor torque decrease is within the limits applicable for the specific conveyor length and belting used, there is no practical need to develop a complex procedure for such a slow down of a conveyor.

It is important to state that this is, in a way, a compromise solution. This type of control will be effective as long as the drives are powered. Consequently, the design must take into account cases when stopping occurs as a result of a power supply disruption. This may affect the design and selection of conveyor components.

Figure 11 shows a controlled stop utilising a variable fill fluid coupling.

In this case oil is drained from the coupling over a period of 10 sec.

With the oil draining, additional benefit may be achieved. In some cases conveyors, as a result of the specific operation of the system, stop and start frequently putting additional demand on the motor and coupling. If this is the case, the motors may remain running for a period of time even if the conveyor is stationary and ready for re-start “on demand”. In fact, any device which allows de-clutching, may provide such a facility.

5.0 CONCLUSIONS

The paper presented several options of control of a conveyor during transient stages of operation. Some of them have been known and applied for some time, while others have come into being as a result of necessity**.** Current theoretical and practical progress in conveyor technology, allows selection of the best suited method which will provide an optimum solution between costs, performance and operational demands.

6.0 REFERENCES

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