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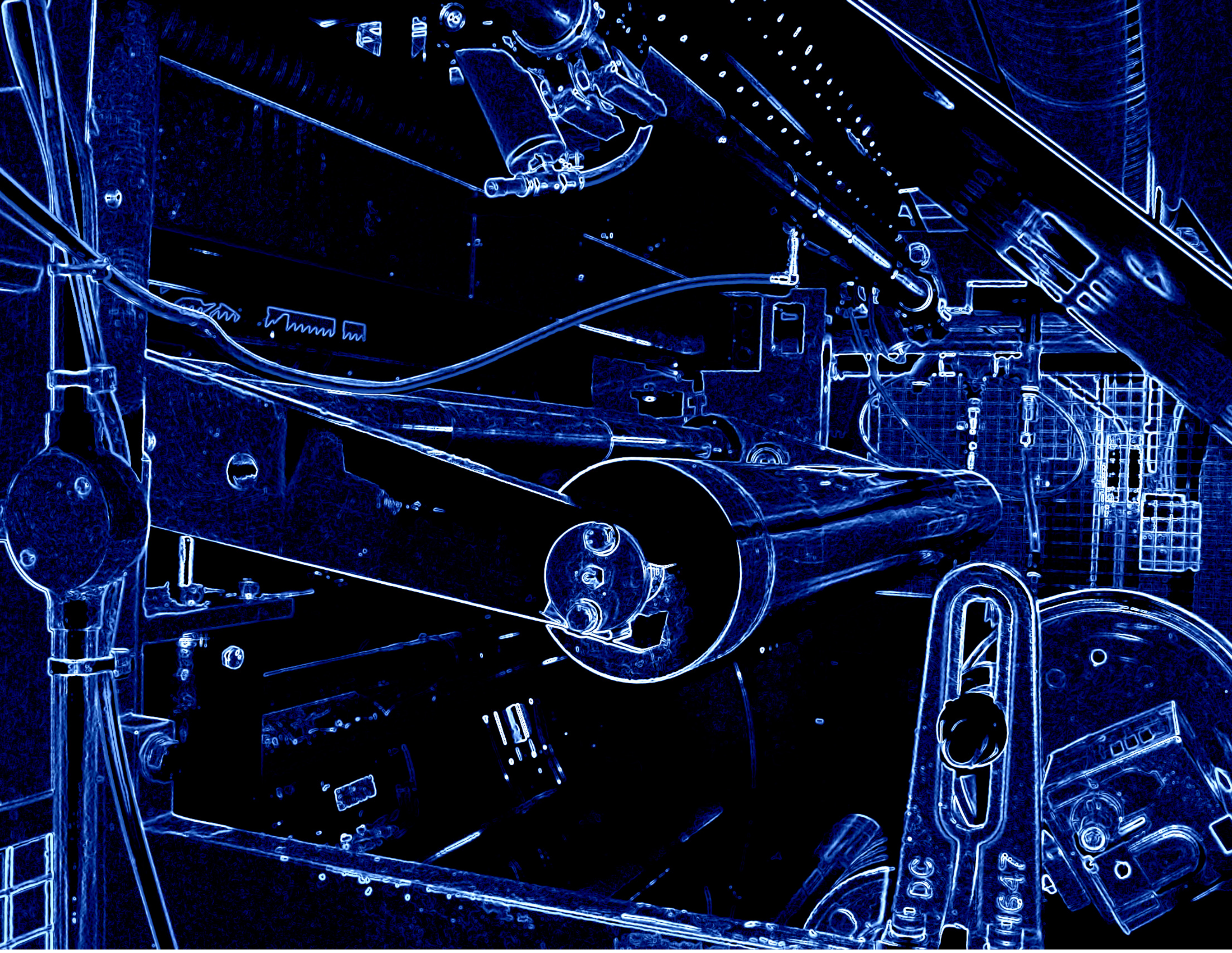
Improving the production process through better web tension control



The significance of web tension control

Web tension effect achieved when opposing longitudinal forces are exerted on any substrate (e.g. paper, film, board, cable etc.). Experts in the converting and printing processes know how critical good tension control is to their process and that tension can represent a single point of failure during production. Accurate and stable tension control on driven material ensures:

- Higher quality product
- less scrap and, therefore, improved productivity
- higher production speeds
- improved downtime and lower operating costs

Poor tension control – the web being too loose or too tight - causes a number of problems:

- the material wanders, wrinkles, breaks or wraps-up around driven rollers
- unsuccessful splicing and speed changes
- inadequate printing quality due to loss of colour-to-colour registration
- more scrap material and increased downtimes – all bearing a significant cost

Good web tension control systems ensure that no matter how demanding the production process is, the correct web tension is maintained for any type of material, at any point of the machine and at any speed.

Open Loop vs. Closed Loop - What is the difference?

In an open-loop control system there is no direct tension feedback signal so controlled corrective action for any web tension variance is not possible. They operate on a predictive load basis.

In contrast, a closed loop tension system uses a signal (generally an electrical one) that is proportional to the position of a feedback transducer (i.e. load cell or dancer mechanism) that is pre-tensioned as determined by the main process requirements. The control system uses a PID controller (proportional, integral and derivative controllers are essential elements in a tension control system but fall outside the scope of this report)

There is a cost-performance payoff between both alternatives; high performance closed-loop systems provide accurate, consistent tension control. **Colin Keating**, an experienced design engineer at Optima Control Solutions Ltd., talks further about two popular types of closed-loop tension controllers – dancer mechanisms and electrical load cell transducers.

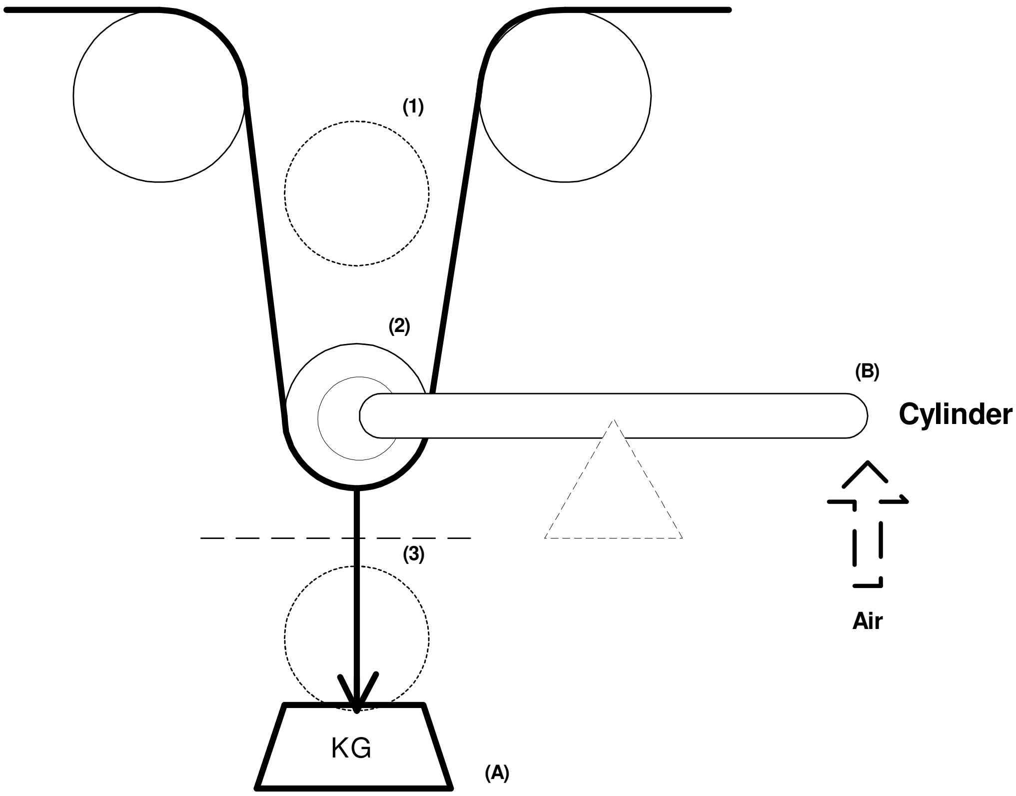


Figure 1. Dancer control system configuration

Dancer control system

The operating principle of a dancer roll is to induce tension on a web type substrate through a mechanical mechanism (see diagram above). The simplest way to impart load on a dancer mechanism is by hanging weights (**A**) where the load is regulated by varying the amount of weight so imparting different tension on the web.

A more common method of loading a dancer mechanism involves a pneumatic cylinder, attached at the sides of the dancer arms, which by varying the pneumatic load (by hand valve or Electrical to Pneumatic (E-P) transducer) allows a more easily adjustable and reliable load setting method for machine operators (**B**).

There are pros and cons with both alternatives, in complexity, accuracy and cost. Some processes (e.g. flying splice mechanisms) almost exclusively use dancer mechanisms because of the web accumulation features they naturally provide, they do however provide a less consistent steady-state performance when compared with load cells.

From a control system point of view, a dancer is slightly easier to commission because its working principle is based on a broad position range rather than the narrow range of the load cell tension transducers.

Example
The system described in the diagram above employs an electronic regulator (an AC or DC drive, not shown) to control the web substrate as required by the process. The feedback signal is fed back to the regulator in which a PI controller is used to “tune” its response.

The figure shows a target dancer roll position, shown as (**2**). As the dancer travels up to (**1**) and down to (**3**), an error value is sent to the controlling drive. The drive then automatically adjusts the dancers position back to the desired value. The system is designed to keep the dancer at the designated target position (**2**). The fact that one can actually see the mechanical adjustments in a dancer configuration makes it easier to commission whereas a load cell arrangement has no visible mechanical movement.

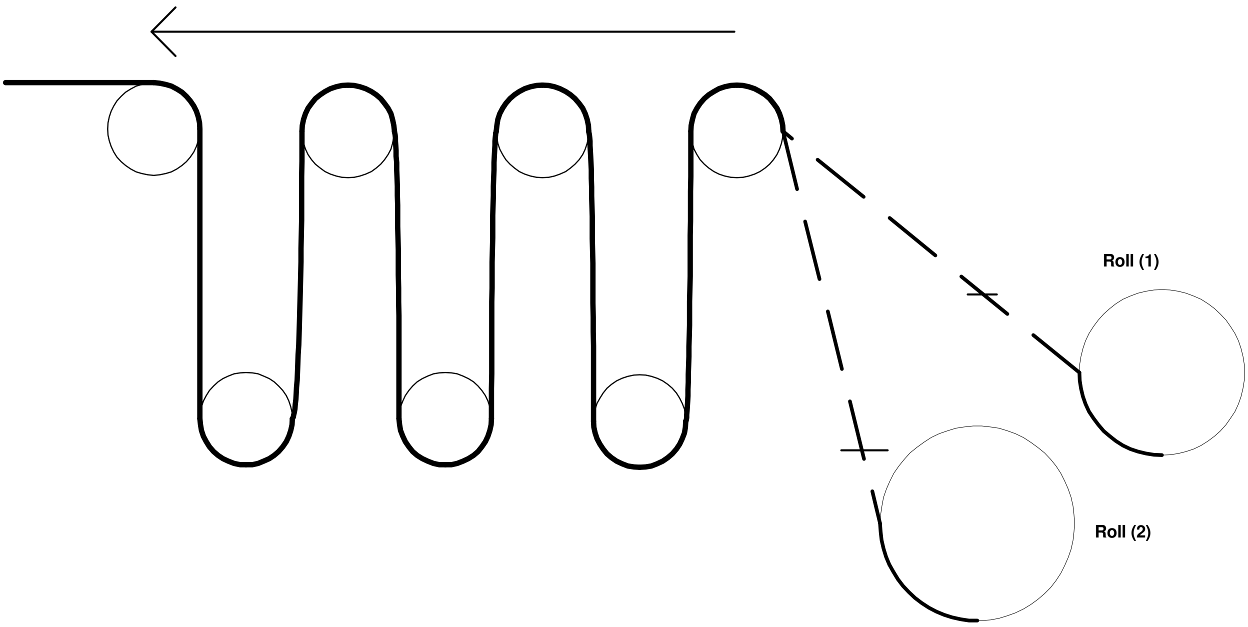


Figure 2. Zero speed butt splice winder

As mentioned earlier, some applications where a dancer is often specified are when the process requires the accumulation of material (**figure 2**). E.g when used for joining material in zero speed butt splice winders. Flying splice winders are a physically dynamic application; here, a dancer provides essential web accumulation, necessary because for small errors, the system will experience dancer position change, but the web will never lose contact with the dancer roll so maintaining a constant and controlled substrate upon which the joining process can be carried out.

Were a load cell be employed the very slightest, sharp disturbance in web stability will cause the it to lose contact with the roller which, in turn can cause process problems or web breaks.

It is obvious that dancers can be much easier to use a control system viewpoint. However, load cells are mechanically simpler and more accurate. Determining which is best for one’s application depends on a range of factors (substrate material, machine type, dynamic response required etc.).

There are drawbacks with dancer control systems that need to be considered. Perhaps one of the most obvious one is the complex mechanical design requirement. Dancers are difficult to engineer and install. Because dancers are position controllers, they cannot read tension values and require a more complicated algorithm to 'translate' tension values into positioning values.

Advantages of dancer control systems	**Disadvantages of dancer control systems**
Easy to set up	Difficult to design mechanically
Ability to accumulate web; more 'forgiving' of variation in speed	No direct capability of measuring and responding to tension values
Easy to commission and debug	Low tensions are problematic – the dancer induces more tension from mechanics

Load cells – tension transducer control system

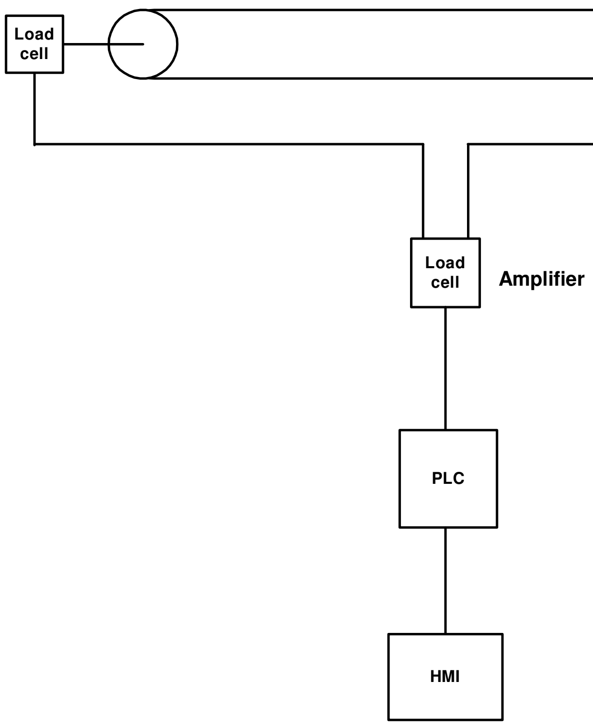
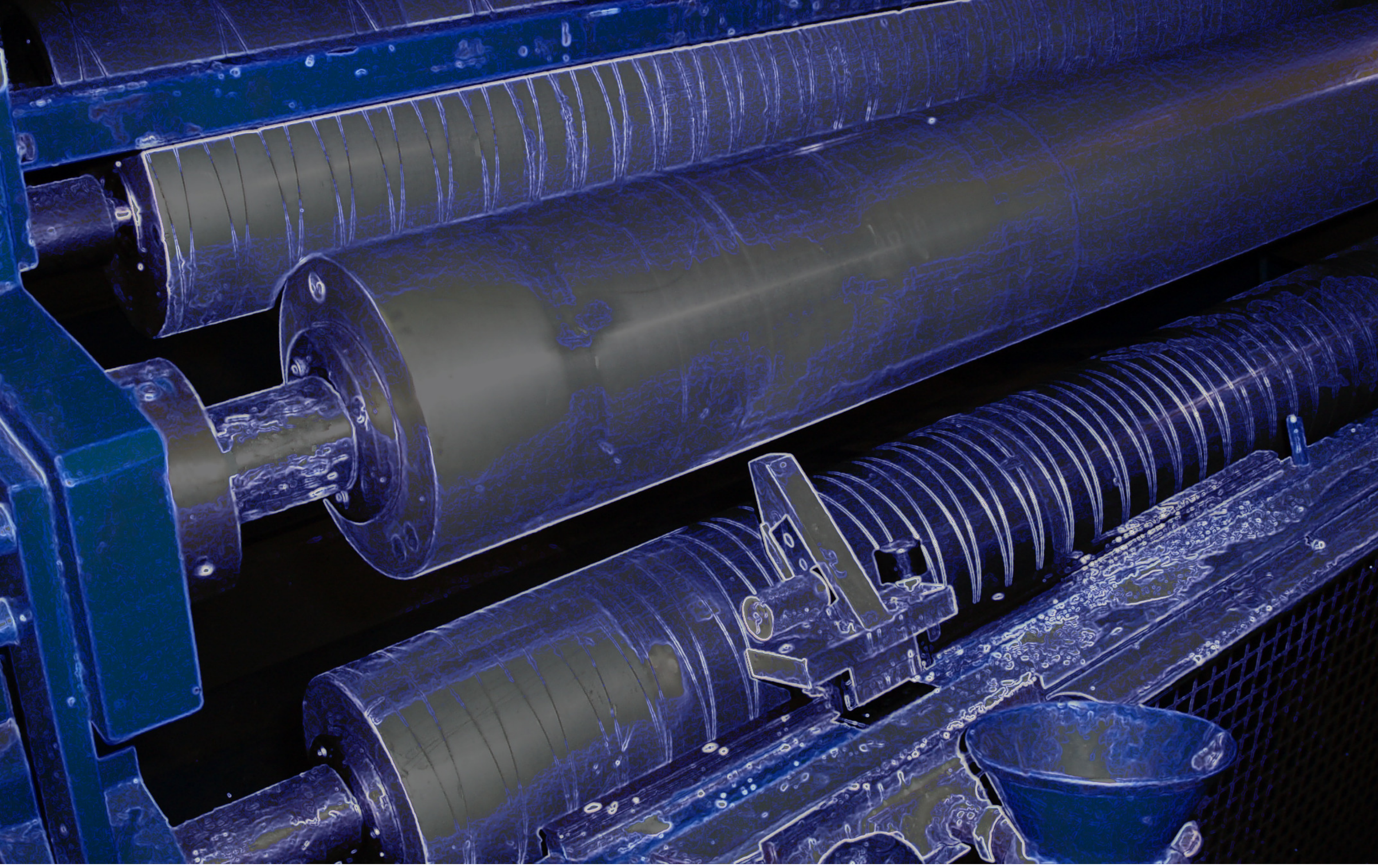


Figure 3. Simple load cell arrangement



There are various types of load cells, each defined by their mechanical configuration e.g. Pillow block and cartridge types.

Load cells (**see figure 3**) are constructed using strain gauges (components with resistance properties that varies proportionally with physical deflection). By mounting the strain gauges on a metal beam (with known deflective characteristics) in a bridge configuration a signal proportional to the beams deflection is generated. When applied in a web tension application, with load cell transducers typically mounted at each end of a roller on a machine (over which the web being controlled is passed) they are employed to provide a linear signal directly proportional to the tension applied. This signal is fed back to the control system (as per the dancer system) and control achieved in a similar way.

The minimal yet predictable deflection required to generate the signal means these transducers are used in high performance web control applications. Their simple construction along with the physical properties has made these components extremely popular in web transport applications.

Advantages of load cells	**Disadvantages of load cells**
Accurate flexible measurement and control of tension	Not responsive to disturbances in the production process.
Low maintenance requirement due to simple arrangement	Harder to commission and debug
Compatible with digital communication networs	

Colin Keating has been part of Optima's engineering team since 2007. Web transport applications are among his specialist disciplines. With more than 19 years of control systems engineering experience, Colin talks here about the two closed loop web control systems from a practical point of view.

[Colin, so far, you have been talking about the basic principles, pros and cons of both dancer rolls and load cells. Are dancers easier to maintain for maintenance engineers on a production site?]

Not necessarily. Load cells are mechanically simpler than dancers. The only moving (wearing) part on a load cell is a bearing that it is quite easy to replace. With a more complex dancer system in contrast, one needs to maintain whatever the pivot point is (whether it is a cylinder, or chains and weights). Another more technical issue that occurs in dancer systems is the inherent non-linearity of the feedback signal that the mechanical experts need to consider in their designs. The mechanical parts must not tighten the web.

[Can you recall any particular projects that you have engineered involving dancers?]

The most impressive project I can think of is one that we supplied to a customer in Kings Lynn. Their printing machine had a flying splice winder section. I remember it because in short, someone had removed the original dancer mechanism (it used weights) and replaced it with a load cell arrangement believing that the load cell would provide better accuracy. The machine would then only splice for 1 out of 3 attempts; clearly unsustainable. They contacted Optima for our advice. Experience told us that the application needed a dancer mechanism but a much more modern arrangement. The difficulties in using load cells on a flying splice were now all too apparent to the client.

They found that when switching the tension control from one roll to the next one, in the splicing sequence, the whole control system was disturbed within a fraction of a second and using the load cell meant it lost tension. We engineered a new dancer system with very low friction components and achieved reliable splicing for them with ease.

Most of the flying splices we have done have dancers because of the accumulation advantage mentioned earlier. If a load cell is used for this type of process, the disturbance created by other splicing component rolls and knifes can easily cause the web to jump off the roll. The dancer absorbs the shock and allows the control system to overcome the short disruption.

[What about load cells? What circumstances necessitate their use?]

Certain pieces of equipment need the material to be at a guaranteed tension. A printing press, for example, will need accurate and stable tension control. A print register system ensures that all the colours are printed accurately with respect to one-another It will only work well if the substrate being printed on is stable and running at the correct tension value. The printer will need to control his substrate flexibly and accurately to accommodate different materials. Another common requirement is for the tension levels to be different for various sections on a machine. If the web is transported or wound at too low a tension it can wander from side to side causing process problems (e.g. print registration issues) or poor winder performance (the so-called “telescope” phenomena).

Conversely, too much tension can deform a substrate or cause problems on the surface of the material.

One obvious advantage using load cells is their operational flexibility. Operators change the web tension simply by changing a number on a HMI or a potentiometer dial. It is possible to make adjustments to dancer system in a similar way using E-P transducers (**see figure 1**), but still the whole system is not as flexible.

[What are the recent technological developments for load cells?]

At present, load cell technology is so widely developed that dancers have become the more costly solution. Also, in applications where low web tension is required, dancers are not suitable – dancers contain inherent mass and inertia that the web must overcome.

The most significant innovation on the load cell control technology is the shift towards digital controls. The latest load cell amplifiers employ intelligent tuning techniques and digital communications networks (e.g. ProfiBus).

[What are the typical web tension control issues of our customers?]

Our clients experience a range of issues. Improving process and machine reliability is one reason why they get in touch with us; increasing production speed is another.

e.g. Figure 3 shows a typical retrofit for a printing machine. We have carried out control system upgrades on a wide range of machines from various manufacturers .We have completed projects that involve a straightforward control system upgrade through to more mechanically complex projects where we have removed existing line shaft arrangements and introduced individual section controls providing faster setup times and much better flexibility for the operators.

The majority of our customer applications use load cells, not dancers, though understanding which applications necessitate the use of one or the other (or a combination of the two technologies) means we still employ dancers where the process requires. This is where Optima have a great deal of expertise and experience. As per our example, a butt splicer might work easily with a load cell system but it is a different story for flying splice winders, this type of knowledge is critical to a projects success.

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