Minimizing Life Cycle Costs with Modern Consistency Transmitters

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ABSTRACT

The basic design of common consistency transmitters, (rotary and blade type) has remained the same for over 40 years. Over that period only the electronics have been modernized, because of obsolete components and partly to improve performance. Communication of the transmitters has developed and manufacturers have added several new digital communication protocols to enable the transmitter to communicate with the automation systems, like HART®, Fieldbus, FDT/DTM and AMS.

The drawbacks of the old designs are related to installation, maintenance and repairs. Old rotaries with massive structure require pipe expansions for less than 300mm (12") pipes. The motors are 3-phase motors and they need a high voltage supply with contactors and overload protectors. The drive belt wears and is a maintenance item. For a service check up, repair or cleaning of the sensing element, a user must wait as the line is drained before removing the sensor.

In the new design of the rotary transmitter, by Kajaani Process Measurements Ltd, the squirrel cage motor is replaced with a direct drive servo motor which is integrated with the drive shaft. This has resulted in a drastically smaller size, a 60 % decrease in weight, and the elimination of drive belt and the 3-phase high voltage in the sensor. Perhaps the most important feature of the new KC/5 rotary sensor is that it can be inserted in and removed from the process while the process is running.

Blade transmitters have had problems with seal failures because of the shear force transfer mechanism causing liquid leakage from the process into the sensor through the seals, causing total damage for the transmitter requiring expensive repairs or a unit exchange.

The new, seal-less design for blade transmitters prevents liquid leaks into the transmitter. The very strong and reliable process diaphragm does not have any hysteresis, offering excellent sensitivity and measurement accuracy. This strong diaphragm offers safe working conditions and enables users to replace electronic components without shutting down the process and without draining the line. The new KC/3 blade transmitter can be fully maintained and repaired on-site without sending it to manufacturer for service.

This paper highlights safety, life-cycle costs, performance and maintenance features with the new designs and constructions used in modern consistency transmitters.

INTRODUCTION

In the market, there are two types of consistency transmitters based on shear force principles – the blade and the rotating transmitters. Out of these, the rotating type consistency transmitters are widely considered more accurate and repeatable. A reason for this perception is that the rotating transmitters are less strict with respect to the installation requirements. They work in locations where the blades are inadequate or there have been installation mistakes, which is the single biggest reason for non-working blade applications.

Unlike the blade transmitters, the rotating transmitters do not require laminar flow conditions. A user has more freedom in selecting the location. The rotating one does not need long straight pipe sections. It can be placed closer to a dilution valve or a pump to gain faster control loops. The protector blades and flow stabilizers, often recommended for the blades, are not needed either. The rotating transmitters have a wider flow range starting basically from zero. They can be applied even to open stuff boxes and tanks.

The suppliers of the rotating consistency transmitters - only a few in the world - have enjoyed a strong market position without pressing need for improvements. Perhaps this sense of comfortableness has lulled the suppliers into the illusion that there is no reason to spend resources on development, whereas the blade suppliers have actively tried to catch up and overcome the technology disadvantage. However, the blade type transmitters have the cost benefit over the rotary, that's why blade transmitters are very common in the pulp and paper industry, especially in non critical applications.

The successful paper and pulp mills have demanded better performance, reliability and lower life cycle costs for consistency transmitters.

CONVENTIONAL DESIGNS

Basic design of the rotating consistency transmitters dates back to 1960's. The structure contains a squirrel cage motor - normally a 3-phase motor - which rotates the sensing element inside a process pipe with the help of a drive belt or a gearbox. The sensor is mounted in a spool piece or there is a flange in the sensor body which is bolted on the flange of a welded stud. The massive size of the sensor requires a pipe extension for the lines smaller than 300mm (12"). The mechanical, electromechanical, and installation solutions of the rotating transmitters have remained the same for decades.

Since the beginning, only the measurement electronics has been modernized, partly perforce because of obsolete components, and partly to improve performance. The concept "smart" has been introduced when the user interfaces have been redesigned to be more user-friendly with the help of the new microprocessor technology.

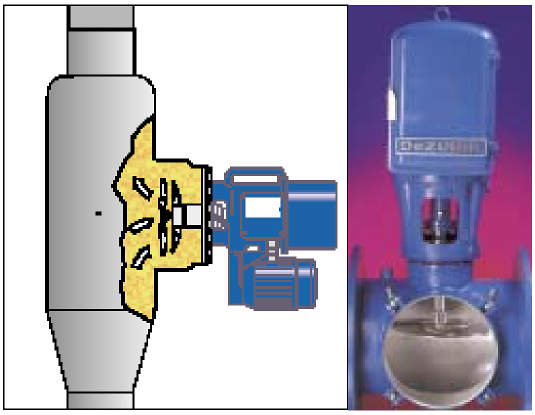

Figure 1. Installation techniques of the rotating consistency transmitters. A flange mounted with the measurement chamber on the left, a spool piece installation on the right.

The drawbacks of the old design are mainly related to installation and maintenance. A 3-phase induction motor requires installation by contactors and overload protection. The trend with electrical safety regulation is to eliminate dangerous high voltage from field instruments. The modern field instruments are either fully operated by a low voltage DC or they have a separate power unit which provides the DC-voltage required by the sensor. The power unit can be mounted on a wall and in a place where the handling of high voltage is safer.

The rotating consistency transmitters have rotating parts which wear. A worn out drive belt cannot be replaced without hauling the sensor to the workshop. The mechanical seals have limited lifetime. Changing of the seals requires removal of the sensor from the process. To remove the sensor, the line has to be drained first.

If the line size is less than 300mm (12") the sensor cannot be installed without a pipe expansion. For the bigger pipes some models have process connections which are welded on the side of process pipes. Anyway, the installation is fixed – a sensor cannot be removed for service without process stoppage. At pulp mills several months may elapse before a suitable, long enough for draining, shutdown occurs.

A North American company APPA Systems Inc, made a first serious attempt in decades to improve the serviceability and installability of the rotating transmitters. The company developed a sensor which is installed into a process through a gate valve. The sensor is "screwed out" from the line for service with the help of the patented spiral insertion mechanism until the gate valve can be closed. At the same time, the mechanical size of the sensor was reduced to keep the gate valve size reasonable. As a bonus, the minimum size of the process pipe dropped down to 6". Instead of a 3-phase motor the company selected a single phase motor to reduce the installation costs of the power supply.

Excluding the installation related improvements the design relied on conventional solutions. Although the high voltage 3-phase power was changed to the lower 1-phase voltage, the line voltage was still connected to the sensor. The motor was a conventional induction motor and it rotated the drive shaft with the help of the drive belt. These models have been sold mainly in North America and for the applications where the sensing element for any reason has to be cleaned frequently from scaled or trapped material.

Figure 2. The rotating consistency transmitter installed through the gate valve.

Blade transmitters have also been in the market for over fifty years. Most of the suppliers have developed the in-built electronics and its features. The weakest point has been the mechanical sealing of the shear force transfer mechanism. With all previous designs, the sealing is done with the O-ring, which evidently loses its sealing properties, causing process liquid to leak inside the sensor damaging the electronics. Particularly in very harsh and demanding applications, such as pulp mill applications, the lifetime of blade transmitters can sometimes be been very short.

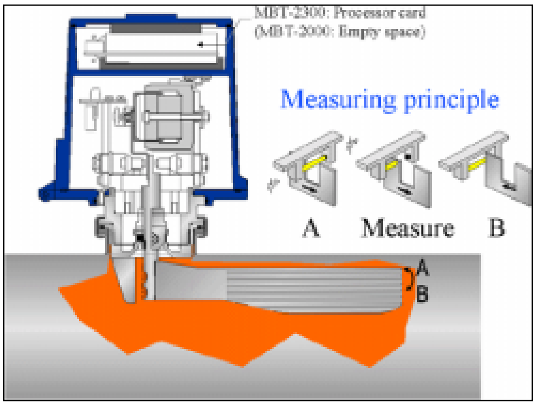

Figure 3. Conventional design moving blade type consistency transmitter.

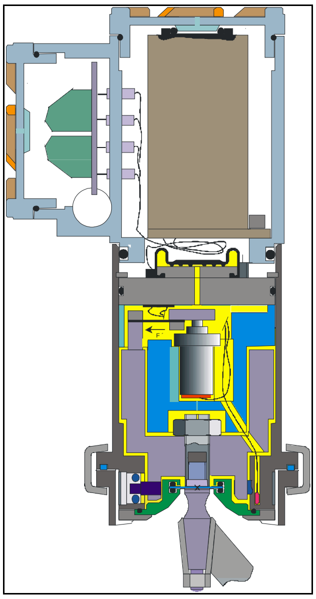

Figure 4. Conventional design static blade type consistency transmitter.

NEW GENERATION TRANSMITTERS

Kajaani Process Measurements Ltd. decided to approach the installation and maintenance issues from a completely new view.

The new Rotary transmitter's maintenance items motor and drive belt were eliminated by replacing the conventional induction motor with a direct drive servo motor. The motor is integrated with the drive shaft. This design has several advantages over the old ones:

- Drive belt (prone to wear) is no longer needed. No more maintenance.
- Motor has no parts prone to wear; no brushes nor bearings.
- Servo motor is powered by 48 VDC. Line voltage eliminated from the sensor.
- Weight of the sensor dropped drastically to less than 50% compared to the old models in the market. In maintenance situations one person can handle the unit without cranes or winches.

Figure 5. The direct drive consistency transmitter can be inserted or removed from the process while the process is running.

The new design is installed through an isolation valve. It can be serviced when the need arises without waiting for a long enough stoppage for draining the line. A maintenance outage can be devoted to machinery which cannot be taken care of process running. The removable instruments can be serviced later with better time and without all the hassle one would expect with a normal maintenance shutdown. Cleaning of the in-line sensors should be done immediately when the scaling happens. The sensors do not fail comfortably just before a scheduled shutdown – on the contrary the probability to fail is greatest during a start up. While waiting for the next stoppage an instrument is not in control. In a manually run process, the disturbances get through and cause quality variations, over usage of chemicals, and generate runnability problems.

At the time this article was written, the new design was the only shear force consistency transmitter which can be removed from the process while the process is on.

When a drive belt is used it has to be tight. Tension pulls the drive shaft sideways and generates stress on the shaft bearings. In the integrated design, the rotor is mounted directly onto the driveshaft, which rotates symmetrically inside the stator. The balanced design eliminates any side forces and strains on the bearings increasing the lifetime of the wearing parts and reducing the need for further maintenance. The structure becomes robust with less steel – a reason for dropped weight.

The direct drive motor is completely software controlled. As opposed to the fixed revolution induction motors, the rotation speed can be easily changed. For practical reasons the rpm range is limited from 300 to 650. How fast the sensing element is rotated depends on the application. E.g. at lower consistencies the sensitivity can be increased by increasing the speed and at high consistency the other way around. This feature makes the usable consistency range exceptionally wide – from 1.5 to 16% - with only one type of sensing element. Only one type of sensor is needed as a spare to cover all the applications.

Change of the rotation direction is also easy. The new type transmitter even has the auto-reverse function – the unit is programmed to reverse at preset intervals. Plastic strips or other foreign particles traveling with the slurry can get wrapped around or trapped on the sensing element. Running reversed helps to remove the stuck material without removing the sensor from the line for cleaning. With reverse rotation the sensor can automatically perform zero calibration and adjust it over time if necessary, benefiting the sensor zero calibration in that it never drifts and sensor stability remains excellent over its entire life cycle.

Kajaani Process Measurement Ltd has also designed and patented their unique new type blade type consistency transmitter KC/3. Its 2 mm thick titanium diagram does not have any O-rings and leaking points. It makes it possible to have much higher reliability for the process diagram in harsh installation locations, added with superior performance. In addition, benefits are a safe working environment to replace electronic components without taking the transmitter out from the pipeline. The new type of blade transmitter KC/3 is fully field-repairable and never needs factory service by the manufacturer, eliminating expensive shipping to manufacturer and eliminating the need for spare sensors in stock.

The KC/3 is strong enough to be applied to the continuous digester blow line, and paper machine broke lines, where several references have proven the robustness and performance of unit.

Figure 6. KC/3 blade type transmitter does not need a shutdown if electronics needs to be replaced.

MAINTENANCE

The maintenance approach of the conventional rotating transmitters has remained the same for decades. After a failure, one waits for the next shutdown in order to be able to drain the line and remove the sensor. In case of a short stoppage there is no time to repair the sensor; typically service takes 4-8 hours in addition to removal. The failed unit is replaced with a spare unit or the process is operated manually until the next outage.

Changing the belt or the mechanical seals of a conventional design rotary transmitter is a major service operation. Very few mills have the required special tools or know-how. In practice, a customer orders the supplier's specialist to the mill, or ships the unit to the supplier's service center for rebuild. In any case the cost of a rebuild is significant. It has been calculated that the typical annual maintenance expense of the older rotating transmitters is in order of 20-30% of the purchase price of a new one.

The basic design criteria of the new design was to develop a transmitter which can be serviced by the customer without special tools and special training.

To start with, the new generation transmitter can be removed from the process for service without waiting for a suitable stoppage.

Removal of the sensor does not require a team of technicians, but one person can handle the tasks from the beginning to the very end. There is no drive belt to be changed, nor to worry about wear of the motor. Change of the mechanical seals has been made simple – a mill technician manages it in one hour without special training. The seals are no part of the measurement itself – seal change does not lead to mechanical tuning and recalibration. The same calibration parameters are valid after the change. The dual seal system – tandem design – increases the expected lifetime of the seals to the maximum.

The blade transmitter KC/3 has been designed so it can be serviced by the mill personnel without any special tools or knowledge. There are no items/parts requiring maintenance, like seals or O-rings. All electrical parts can be replaced at any time, safely, without shutting down the process. The diaphragm in the process connection is 2mm thick titanium, preventing the process leakages even with 25bar pressure and harsh process conditions. If any electronic part needs to be changed, the transmitter does not need to be taken out from the process, so there is no need for shutting down the process and draining the line.

DIAGNOSTICS

Self-diagnostics is a wish which pops up often in discussions with the customers. The microprocessors have been used in the conventional transmitters mainly to help in calibration or operating the display. The modern processor technology enables much wider set of tasks, such as monitoring the internal functions and signal trends. The sensor can judge if the measurement result is rational or if it is time to do some maintenance work.

The new transmitters have the build-in maintenance menu. In addition to internal signals, the processor monitors the behavior of the process. Deviations from the norm are classified into three categories, depending on seriousness of the abnormal behavior. The fatal deviations set the mA output to the error state which tells the DCS that the sensor is out of order. The user can check from the special registers what errors the diagnostics has found and hints how to correct the situation. In less serious situations the alarm is activated together with storing the error code into the register, but the measurement continues otherwise normally. The informative data on internal signals and process is gathered to the on-line signal register where a user can go and flip over the data if needed.

As an example of how to make use of the process data, let's take abnormal process behaviour. The new designs have the "shock-counter". It keeps track of abnormally high consistency readings, spikes. The data on the 5 highest peaks also contains amplitude (torque or grams) and they are time stamped. These shocks may not have any effect on the performance of the meter itself. If a pH-probe located close to the sensor has broken the user can go and check the consistency transmitter register to see if some hits have been recorded and if they coincide with the failure. If the peak can be timed, let's say, with a start up the user can check if the stoppage procedures have been followed – such as flushing the lines – or if the procedures need to be revised.

The mechanical seals are the wearing parts of any rotating transmitter. Typically seals last for 3-5 years. The new design continuously monitors the friction of the seals and the drive shaft bearings. When the seals and bearings wear out, the level of friction increases. At a preset friction level the unit gives a pre-warning about any upcoming maintenance need.

The new blade type sensor has not any maintenance items or parts like O-rings etc, so it does not require preventative maintenance at all.

ABOUT APPLICATIONS

The most common technologies to measure consistencies are shear force, time of flight or phase difference of a microwave, and optical measurements. Out of these principles the shear force techniques is overwhelmingly the most common one.

In the pulp mills, the high conductivity of the pulp slurries eliminates the use of the microwave technology. The microwave simply dies out in the suspensions, having high concentration of chemicals. A problem with the optical transmitters is varying color due to cooking liquor carry-overs and brightness. In practice, the shear force principle is the only working technology in the pulp mills.

In the early parts of a fibre line the pulp suspension contains high amount of coarse material which hammer any piece protruding inside the pipe. The blade type transmitters are always in the main flow. They are apt to receive hits and fail occasionally. The sensing element of most of the rotating transmitters is installed in a pocket out from the main flow and is protected from direct hits.

Serviceability is a key advantage of the new generation transmitters. The pulp mills are seldom stopped and even more seldom the lines are drained empty. When a transmitter fails it can take months until a non-removable sensor can be serviced. The most important control applications are often secured by installing two, even three sensors to that location. The new design rotary transmitter can be removed whenever needed. The gate valve is available up to 25 Bar (362 psi) pressure, making the removability feature available for basically all the applications. The new type blade transmitter can be serviced without shutting down the process.

The pulp mills are built tight. Freedom to install a rotary transmitter close to pumps and valves makes it easier to place the sensor. To locate a blade transmitter, so that it functions satisfactorily, is practically impossible without expensive piping modifications.

CONCLUSIONS

In the new rotary consistency transmitter design, a squirrel cage motor is replaced with a direct drive servo motor which is integrated with the drive shaft. The benefits are smaller size, 60 % lower weight, and elimination of a drive belt and hazardous 3-phase high voltage in the sensor.

Serviceability is another area of strength of the new design. The small size makes it possible to install the sensor through a gate valve. It can be inserted in and removed from the process while the process is running. No other shear force transmitter on the market has this feature.

Table 1 lists differences between the conventional and the new generation rotary transmitters. The most important features are related to installation and maintenance aspects.

The Blade type transmitter offers excellent robustness and serviceability former designs are lacking, making the life cycle cost and inventory cost much smaller than customers are used to.

Table 1. Comparison of conventional and new generation rotating consistency transmitters.

Feature	Conventional	KC/5
Motor	3-phase squirrel cage	Direct drive servo
Power to motor	from 200 VAC up	48 VDC
Overload protection needed	Yes	No
Drive Belt	Yes	No
Sensor weight	36 kg; 80 lbs	15 kg; 33 lbs
Process mounting	Fixed flange	Gate valve
Insertion depth	Fixed	Adjustable
Removal from process	Stoppage, draining of line	On-the-fly
Minimum line size without expansion	300mm (12”)	150mm (6”)
Revolution	Fixed	300-650 RPM, changeable
Rotation direction	Fixed	Changeable by software
Measurement span	<10%, several sensing elements	14%, one sensing element
Seal arrangement	Single seal	Dual seal, tandem design
Removal time from process	1 hour	5 minutes
Belt change time	4-8 hours	N/A
Motor change time	4-8 hours	N/A
Seal change time	4-8 hours	1 hour
Serviced by	Supplier	Customer
Avg. annual maintenance cost	10 – 20 %	2 %

Table 2. Comparison of conventional and new generation blade consistency transmitters.

Specification	KC/3	Conventional Moving Blade	Conventional Static Blade
2-wire	YES	NO, external power supply needed	YES
Max. process T (C)	120	100	120
Wetted parts	Standard Titanium Special Duplex-SS for H_2O_2-applications	Standard AISI316 Titanium optional	Standard AISI316 Titanium optional
Sample button	YES	NO	YES
Calibration	One-point Linear response 8 integrated calibration curves	Non-linear response	One-point Linear response 8 integrated calibration curves
Flow rate compensation	Flow compensated by blade design	Flow sensitive	Flow compensated by blade design
Local display	YES	NO, handheld	YES
Shock counter	YES	NO	NO