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DIAGNOSTICS IN FLUID POWER SYSTEM OF HOT STRIP MILL – THE RESEARCH IN TUT/IHA SINCE 1994

Diagnostics, Servo Valves, Oil Condition Monitoring, Return Line Filter

Hot Strip Mill

In Tampere University of Technology (TUT) in Institute of Hydraulics and Automation (IHA) has been done co-operation in diagnostics of fluid power system with Finnish steel company Rautaruukki Steel. A hydraulic servo system of hot strip mill has been under research. The hot strip mill includes one reversing rougher and six mill stands which are working in sequence. The hydraulic servo system controls the last three mill stands. These are rolling the final thickness of the strip, which lies between 1.4 and 16mm.

AGC Mill Stand

There are two cylinders in every hydraulic controlled mill stand and each cylinder is controlled by two parallel connected servo valves. Therefore the Automatic Gauge Control (AGC) of finishing mill includes 12 servo valves. These directional control servo valves are also used to control the working pressure of the cylinders during calibration phase of mill stand after each workroll changing. This is a very critical phase for the behaviour of the whole system and of course for the condition of the servo valve itself.

Diagnostics in Servo Valves

Most of the system failures in the hot strip mill have some connection to the function of servo valves. This is why the servo valves are needed to be set under on-line condition diagnosis. The characteristics of two servo valves are studied in laboratory test system.

The first tested servo valve one was brand new and the second one was removed from the AGC system because it caused a system failure. Measured results are step response, flow gain, pressure gain and the effect of added contamination to the flow gain. Pressure gain was found to be the most sensitive parameter for diagnostics use in laboratory tests (figure 1).

Pressure Gain

Pressure gain values are calculated from the linear part of the measured I-p -curves (table 1).

Table 1. Pressure gain values of the studied servo valves [1].

	P_s = 70 bar	p_s = 140 bar	p_s = 200 bar
Pressure gain K_p [(bar)/mA], new valve	1070	1440	2000
Pressure gain K_p [(bar)/mA], used valve	390	660	1000

In table 1 is shown that the pressure gain is decreased strongly in the used valve compared to the new one. The full pressure is reached in the new valve when the control signal is about 1 %. But in the used valve (figure 1) the control signal is needed to be bigger than 6 % of the maximum for the same pressure change.

In figure 1 is shown that pressure curves are rather different in actuator ports of the valve though the spool is moved smoothly. That indicates that another control edge of the spool is worn out.

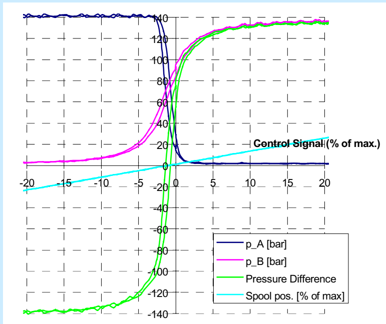

Figure 1. Presssure gain of the used valve (p_s = 140 bar) [1].

Oil Condition Monitoring

Particle Monitors

Different oil condition monitoring possibilities are studied. Measuring equipment for on-line particle counting (table 2) and water-in-oil are tested in laboratory.

Table 2. Particle monitors [2].

Model	FCU 2010	RC1000	CM20 9020	PCM100	2120
Manufacturer	Hydac	Hydac	UCC	Pall	Pamas
Operating method	Optical (laser infrared)	Optical (laser infrared)	Optical (white light)	Mesh	Optical (laser)
Sample time	1 min	1 min	4 min	4…7 min	Adjustable
Continuous operation	yes	yes	no	yes	yes

The results of the monitors were generally within ± one class compared with the reference counter or calculated target level. Only Pall PCM100 was a little optimistic showing two classes lower cleanliness levels when monitoring relatively clean oil.

Effects of Water in Particle Monitors

When using optical particle counters free water causes a rise in the number of large particles. If water is emulsified with oil the number of smaller particles may rise as well. A test was carried out to find out the influence of water in given oil to the accuracy of particle monitors (figure 2). The cleanliness level in the beginning of the test was 12/9. The influence of water on readings disappeared within 20 minutes. The influence of water on particle monitors was permanent only when the actual water content was increased over 1000 ppm.

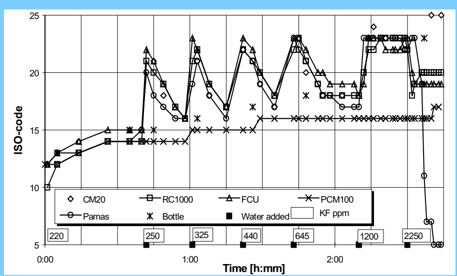

Figure 2. The effect of water on particle monitors (>5µm). [2]

Water Content Monitors

The water content monitors tested are shown in the table 3.

Table 3. Water–in-oil monitors [2].

Model	FCU 2010	Oilan 05-2/91	H2Oil
Manufacturer	Hydac	Kytölä	UCC
Sensor	Ceramic	Optical (IR)	Optical (IR)
Type of water detected	Dissolved	Free	Total
Output range [ppm]	30…400	0…5000	0…30000
Response time	20 min	20 sec	90 sec

The oil temperature was kept at +50°C during the test. Readings of monitors as well as calculated and measured water contents are shown in figure 3. The readings of UCC H_2Oil were quite similar with Karl Fischer titration while numbers of Kytölä Oilan (measures free water) were slightly lower as expected. FCU operated logically but on ten times lower scale than the others. All the monitors responded fast to the increased water content. There is an increasing difference between numbers of total water content calculated and measured. The reason for that and downward slopes of the curves is the vaporisation of free water, which was already noticed in the test.

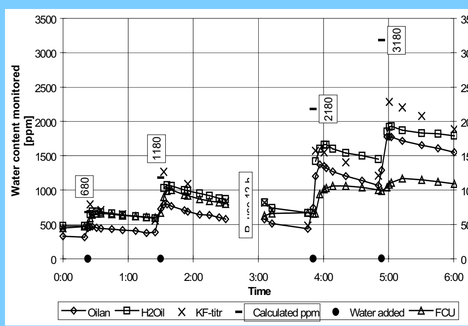

Figure 3. Results of water-in-oil monitors [2].

Diagnostics in Return Line Filter

A diagnosis method for hydraulic return line filter is developed. The difficult measurement of oil flow is changed to easy pressure measurement to make the use of presented analysis possible in practical situations (figure 4).

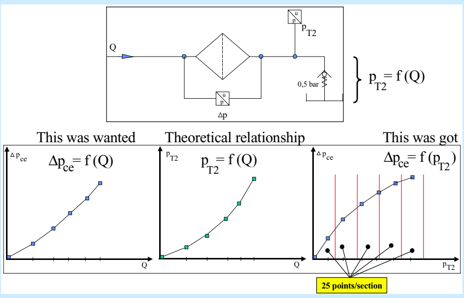

Figure 4. Substituting flow measurement Q with pressure measurement p_{T2} when studing pressure difference of filter element [3].

Trend analysis is used for each condition monitoring signals to get the prediction of system condition in the future (figure 5). Both short time and long time trend analysis modules are developed for industrial use.

The short time trend analysis is suitable to predict quick changes in filter blocking. Quick changes means the changes within few hours or at least within one day. This trend analysis includes one measured mean value in every five minutes. The long time trend analysis is suitable to predict changes during few months.

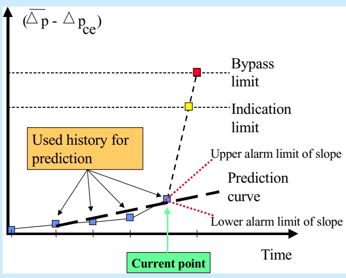

Figure 5. The prediction curve of return line filter with the limits [3].

Conclusions

The most critical things of the hydraulic system in hot strip mill are studied. Many proposals are done to develop and improve the diagnostics of whole AGC system. Most of presented proposals and many more are put in to practice in LabView programmed diagnostics system in Rautaruukki Oyj, Raahe.

References

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