Asset Management and Condition Monitoring

SIEMENS

SIMATIC PCS 7
Monitoring Block “PumpMon”

Function Block for cost-effective Monitoring and Diagnostics of Centrifugal Pumps

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Especially in chemical industries, Asset Management and Condition Monitoring are important tools to increase performance, safety and availability for single processes and the entire plant.
All products and solutions from Siemens based on Totally Integrated Automation are equipped with monitoring functions: i.e. our components for automation and drive systems, communication and switch gear modules, industrial controls, field devices, process instrumentation, sensors and analytics.
For our process control system SIMATIC PCS 7 a monitoring block for centrifugal pumps is available.
This paper describes this „PumpMon“ block.

Content

Description of the Monitoring Block for Centrifugal Pumps

1. Benefits

Power and process plants play a key role in the manufacture of virtually every product on the market today.

Pumps are among the most important machines used in these plants. Around 20% of the world's electrical energy consumption in production is used by pumps. If a pump fails, this can cause an entire plant to shut down and the resulting losses can quickly exceed the value of the pump many times over.

This is why the availability of pumps is an extremely important factor. Redundant systems and special monitoring systems are sometimes implemented to ensure the required availability, but they can be very expensive and complex.

The scope for saving energy, on the other hand, has yet to be fully leveraged.

The PumpMon block for monitoring PCS 7 centrifugal pumps was developed as a cost-efficient monitoring solution and to leverage potential for saving energy.

Picture 1: Centrifugal Pump

PumpMon is used to:

- warn against potential damage to pumps under unfavorable operating conditions
- provide early warning of developing damage to pumps
- optimize the pump design over the long term by means of statistical analysis of the operating data (recording of the load profile)

The block can be used for electrically driven centrifugal pumps with constant or variable speed.

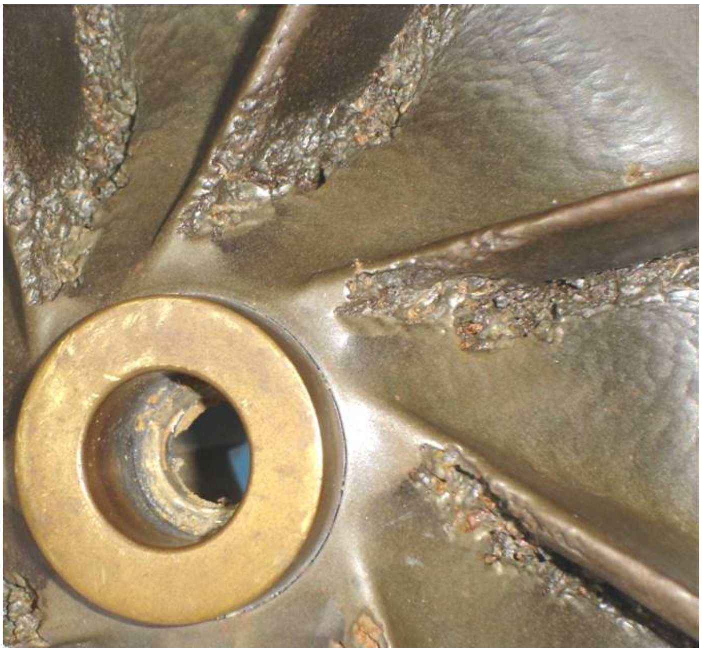
PumpMon can inform operators of any violations of the nominal pump operating range and of deviations from the expected characteristic, and makes this data available for further processing via the block outputs. Of course, all the values can be processed further by means of the usual PCS 7 tools (calculations, trend recording, alarm history, and so on).

The block itself is designed purely for diagnostic purposes and, as such, does not intervene directly in the operation of the pump. This means that it can be deployed, or even retrofitted, without the risk of affecting the process. If required, active intervention (e.g. to reduce the speed of the pump in response to imminent cavitation) can be undertaken by evaluating the block outputs.

2. Requirements

The following data must be known to parameterize the block:

- Measured values:
  - flow rate of pumped medium
  - effective electrical power intake of the motor
  - delivery pressure
  - for cavitation detection in addition: intake pressure, medium temperature (if not constant)
  - pump speed (for variable-speed pumps)
- Values to be parametrized:
  - rated power and efficiency of motor
  - rated speed for variable-speed pumps
  - minimum and rated flow of pump
  - medium density
  - characteristics for delivery height, pump power requirement and pump efficiency (these can alternatively be teached-in)
  - for cavitation detection in addition: NPSHr characteristic of pump, and (if the medium is not water) vapor pressure coefficients
  - alarm limits
  - for non-standard motors, e.g. canned motors: polynomial for dependency between electrical and mechanical power



Picture 2: Damage in a Pump by Cavitation

3. Calculated Values

The following not direct measurable data is calculated in the block:

- delivery height
- mechanical power fed into the pump
- hydraulic power delivered by the pump
- efficiency of the pump
- the current NPSH value (important for cavitation avoidance)
- deviations from the characteristics
- histograms with the statistic distributions of flow and NPSH reserve

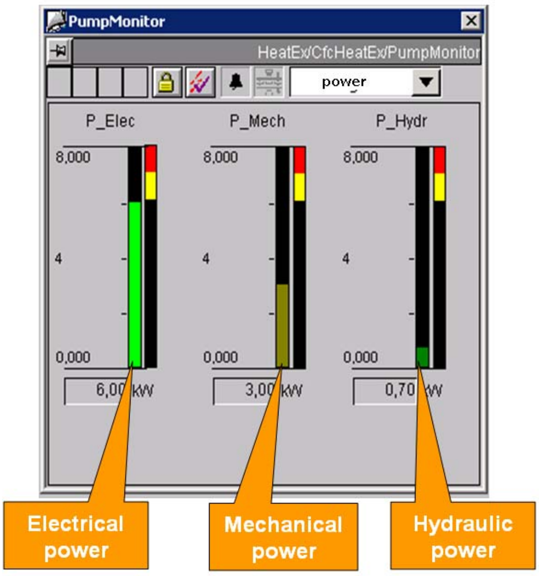
4. Visualisation

The following views are available in the faceplate of the block:

4.1. Power values

Numeric and bar display (including alarm limits) of:

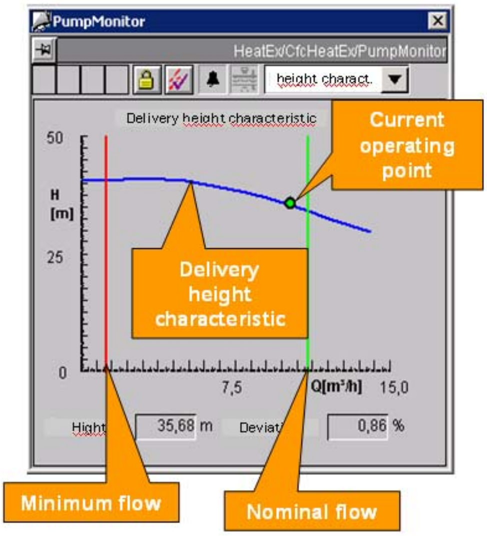
- the measured electric power intake of the motor
- the mechanical power output of the motor as calculated via a motor model – this power is fed into the pump
- the hydaulic power delivered by the pump, as calculated from pressure difference and flow



Picture 3: Power values with alarm limits

4.2. Delivery height characteristic

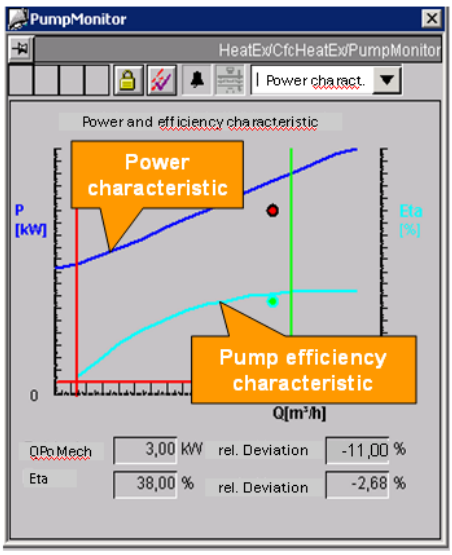
Display of the expected delivery height as a function of flow (in case of speed-controlled pumps converted via the current speed) with minimum and rated flow, „live“ operating point und relative deviation of the operating point from the characteristic



Picture 4: Delivery height characteristic with „live“ operating point

4.3. Power characteristic

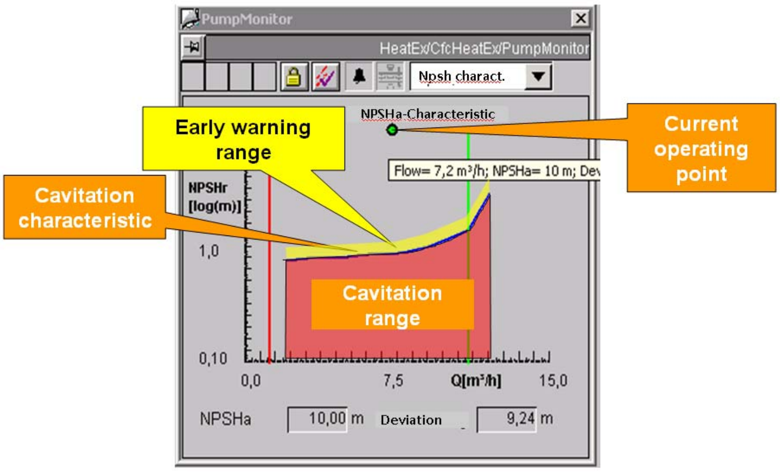
Display of the required (mechanical) pump power as a function of flow with „live“ operating point und relative deviation; in addition display of the expected hydraulic pump efficiency as a function of flow with calculated current efficiency



Picture 5: Power characteristic and efficiency characteristic with current operating points

4.4. NPSH characteristic

Logarithmic display of the NPSHr value required for cavitation-free operation as a function of flow with current NPSHa value (calculated from intake pressure and vapor pressure of medium).

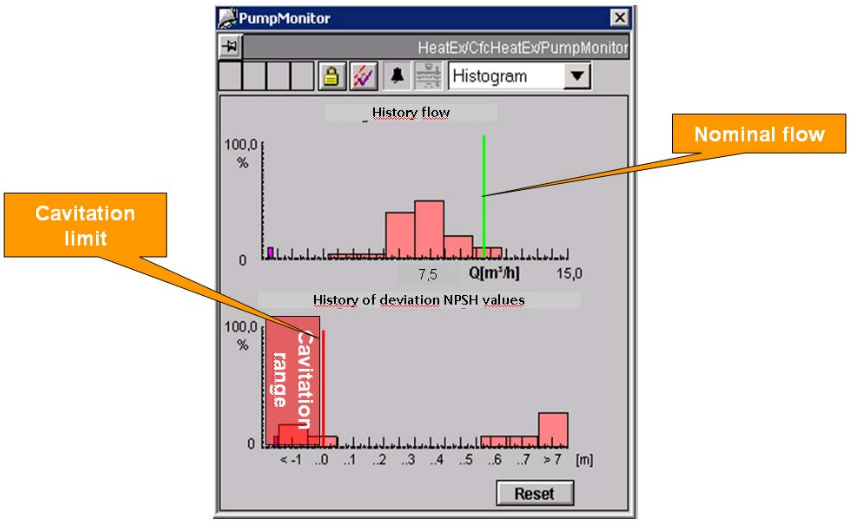


Picture 6: NPSH characteristic with current NPSHa value

Through the calculation of the current NPSHa value, this function block offers the unique advantage of an early cavitation detection. While conventional acoustic or vibration-based systems can only detect cavitation after it has occurred, a pre-alarm can here be initiated before any destructive operating state is reached by checking for a safety-distance of the NPSHa value from the NPSHr characteristic (Default 0,5 m).

4.5. Histograms

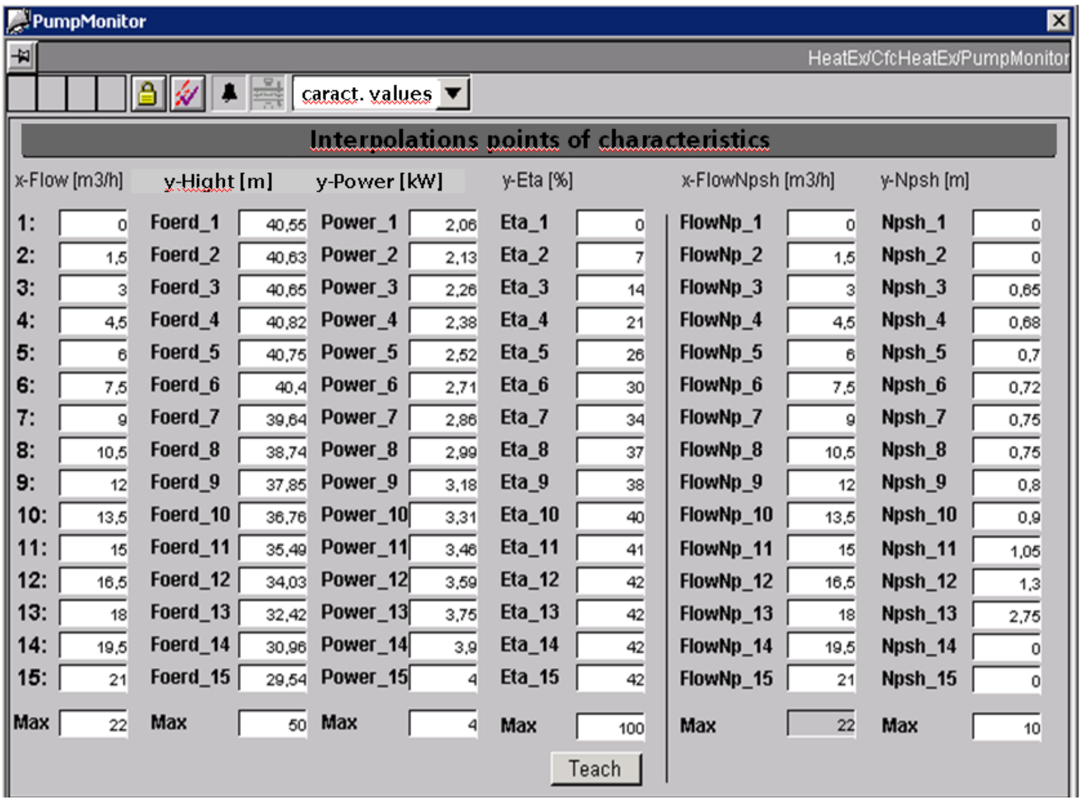
Histograms of the operating states of the pump with respect to flow (above) and cavitation reserve (below).



Picture 7: Histograms of operating states

4.6. Entering the pump characteristics

The pump characteristics can be entered in this view via parameterizing the nodes, or they can be derived from the measured values via a teach-in mode.



x-Flow [m3/h]		y-Hight [m]		y-Power [kW]		y-Eta [%]		x-FlowNpsh [m3/h]		y-Npsh [m]	
1:	0	Foerd_1	40,55	Power_1	2,06	Eta_1	0	FlowNp_1	0	Npsh_1	0
2:	1,5	Foerd_2	40,63	Power_2	2,13	Eta_2	7	FlowNp_2	1,5	Npsh_2	0
3:	3	Foerd_3	40,65	Power_3	2,26	Eta_3	14	FlowNp_3	3	Npsh_3	0,65
4:	4,5	Foerd_4	40,82	Power_4	2,38	Eta_4	21	FlowNp_4	4,5	Npsh_4	0,68
5:	6	Foerd_5	40,75	Power_5	2,52	Eta_5	26	FlowNp_5	6	Npsh_5	0,7
6:	7,5	Foerd_6	40,4	Power_6	2,71	Eta_6	30	FlowNp_6	7,5	Npsh_6	0,72
7:	9	Foerd_7	39,64	Power_7	2,86	Eta_7	34	FlowNp_7	9	Npsh_7	0,75
8:	10,5	Foerd_8	38,74	Power_8	2,99	Eta_8	37	FlowNp_8	10,5	Npsh_8	0,75
9:	12	Foerd_9	37,85	Power_9	3,18	Eta_9	38	FlowNp_9	12	Npsh_9	0,8
10:	13,5	Foerd_10	36,76	Power_10	3,31	Eta_10	40	FlowNp_10	13,5	Npsh_10	0,9
11:	15	Foerd_11	35,49	Power_11	3,46	Eta_11	41	FlowNp_11	15	Npsh_11	1,05
12:	16,5	Foerd_12	34,03	Power_12	3,59	Eta_12	42	FlowNp_12	16,5	Npsh_12	1,3
13:	18	Foerd_13	32,42	Power_13	3,75	Eta_13	42	FlowNp_13	18	Npsh_13	2,75
14:	19,5	Foerd_14	30,96	Power_14	3,9	Eta_14	42	FlowNp_14	19,5	Npsh_14	0
15:	21	Foerd_15	29,54	Power_15	4	Eta_15	42	FlowNp_15	21	Npsh_15	0
Max	22	Max	50	Max	4	Max	100	Max	22	Max	10

Picture 8: Entering the pump characteristics

5. Diagnostic Logic

The block features the following diagnostic functions:

5.1. Generating process alarms to warn operating personnel of unfavourable operating conditions

The following messages can be generated by the block:

- Limit value violation for the three power values (e.g. electrical overload).
- Deviation of the operating point from the flow characteristic (i.e. reduction in delivery height: indication of high gas content, cavitation, blockage, or dry running).
- Deviation of the operating point from the power characteristic.
- Low pump efficiency: determined by means of the deviation of the current pump efficiency from the efficiency characteristic.

- Cavitation: determined by means of the calculated NPSHa value; early warning when a minimum NPSH reserve is undershot
- High gas content: determined by means of the reduction in delivery height
- Blockage: determined on the basis of a limit value for the electrical power being undershot.
- Dry running: determined on the basis of a (second, lower) limit value for the electrical power being undershot.
- Incorrect direction of rotation: (i.e. the motor was connected incorrectly and rotates in the wrong direction): determined when the delivery height falls significantly (> 40%) but with only a slight deviation (< 20%) of the power characteristic.
- Of course, all limits can be adjusted and alarms suppressed as required.

5.2. Generating maintenance alarms to indicate advanced pump wear

This is not performed directly in the block but instead by a downstream AssetMon block (included in the standard scope of delivery of PCS 7). A range of different applications are possible here; a typical scenario would be as follows:

Pump wear is indicated by a long-standing reduction (for hours or days) in the delivery height (high gas content and cavitation can also have the same effect, but this should only be temporary). The "Deviation from flow characteristic" alarm could, therefore, be integrated over time by means of an operating hours counter (included in the standard scope of delivery of PCS 7) and a maintenance alarm ("Pump worn out?") triggered when a particular limit (e.g. three days) is reached.
Current operational experience, however, is insufficient for gauging how large a deviation from the characteristic must be in order to signal imminent pump failure; this is currently being investigated (2007 – 2010) in the research project "ReMain" (see http://www.iml.fraunhofer.de/2227.html).

Another useful diagnostic alarm could be generated when a particular number of operating hours for the pump in cavitation mode is reached. For this purpose, a second operating hours counter would have to be activated when NPSHa < NPSH characteristic. In this case, an alarm ("Pump damaged due to cavitation?") should be triggered after just a few hours in cavitation, but again no generally-applicable rules are yet known for this.

5.3. Generating statistics (displaying the load profile of the pump) to check whether the pump design is correct

1. The diagram at the top of the "Histogram" view shows the distribution of the flow rate values. Ideally, this distribution should reach its maximum close to the optimum operating point of the pump (vertical green line). It is generally presumed, however, that many pumps in the process industry are intentionally overdimensioned, although this means that energy is wasted when the flow rate is controlled by means of throttle valves (which is the usual case). This diagram can help to select a more suitable design when the pump is replaced.

   The diagram at the bottom of the "Histogram" view shows the distribution of the distance of the pump operating point to the NPSH curve ("cavitation reserve"). Ideally, none of the values should fall below 0. If the histogram shows values less than zero, however, the data recorded in the control system can be used to analyze which conditions lead to this cavitation occurence. As more operational experience is gained, however, it may soon be possible to use the operating time in cavitation mode to calculate the remaining service life.

6. Correlation between available measured values and diagnosable problems

	Flow Rate	Pres-sure across Pump	Electr. Power	Intake Pres-sure of Pump	Temp. of Medium	Densi-ty of Medi-um	Vapor Pressure Equation
Blockage	(x) (1)		x (4)				
Dry Running	(x) (1)		x (4)				
High Gas Content	(x) (2)	x				x (6)	
Cavitation	x			x	x (5)		(x) (7)
Wear	x	(x) (3)	x				
Overload			x				
Low Pump Efficiency	x	x	x				

Notes:

(1) Not strictly necessary, but useful for additional plausibility checks.

(2) For correction purposes when the diameters of the intake and discharge stubs are different.

(3) More apparent in the flow characteristic than in the power characteristic.

(4) Used to calculate the mechanical power (more significant than the electrical power).

(5) If not constant.

(6) If not constant; often available as associated value for flow rate measurement.

(7) Implemented in the block for water with a temperature of up to 100°C (Antoine equation); for other media, the respective Antoine coefficients or an external calculation has to be supplied

7. Order Data

Details on the „PumpMon“ monitoring block can be found in the SIMATIC PCS 7 Add-On-Catalogue.

The prices vary according to the number of pumps.

- 6BQ2001-1CA10-0AA0 - PCS7 PumpMon V1.00 TOOLSET
  SW on CD incl. Runtime-Licence (CoL) for 5 pumps
- 6BQ2001-1CB10-0AD0 - PCS7 PumpMon V1.00 LIC RUN
  Runtime-Licence (CoL) for additional 10 pumps within one plant

Supplier: A&D SE SH

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