Additional Information

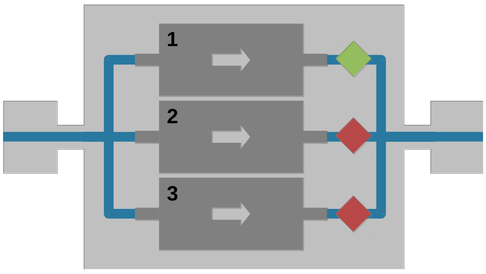
Life time enhancement

There are two concepts for life time enhancements with redundant pumps. The pumps are used in parallel connection and are performance controlled. Some flow measurement device is applied downstream or upstream the pumps to monitor the flow rate.

Serial Control

Here the redundant pumps are used one after each other, i.e. when one pump fails the next is used. Passive valves are installed to prevent back flow through inactive pumps, see Figure 1.

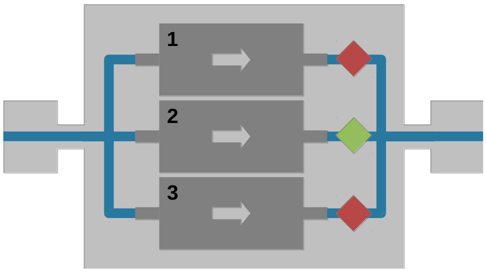
The desired flow rate is achieved by a single pump at amplitude of 20%. Other pumps are inactive. Now the active pump loses some of its performance over time and the amplitude is increased to compensate. Before this pump fails the amplitude is increased further until max amplitude is reached.



	normal mode		partial loss of pump performance		before failure of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate
1	on	20%	on	50%	on	100%
2	off	0%	off	0%	off	0%
3	off	0%	off	0%	off	0%

Figure 1: Control mode of a single pump (no. 1) out of three available redundant pumps.
The colored squares represent passive valves; green color means it is opened by the active pump.

If the pump fails, meaning either the amplitude cannot be increased further to compensate loss or a real damage occurs, the next pump will be activated instead, see Figure 2. This ensures that the flow rate will be kept up.



	normal mode		partial loss of pump performance		before failure of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate
1	failure	0%	failure	0%	failure	0%
2	on	20%	on	50%	on	100%
3	off	0%	off	0%	off	0%

Figure 2: Second pump activated after failure of the first one.

Parallel Control

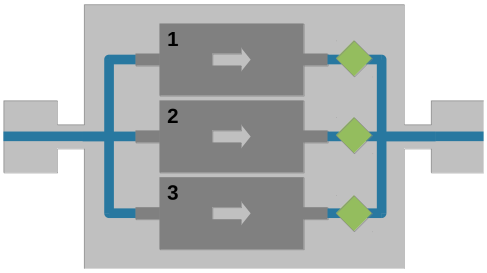
In this concept all of the pumps are active all the time, but are running with low amplitudes.

The sum of flow rates from all pumps will be the desired flow rate.

Now there are two possible solutions with this concept.

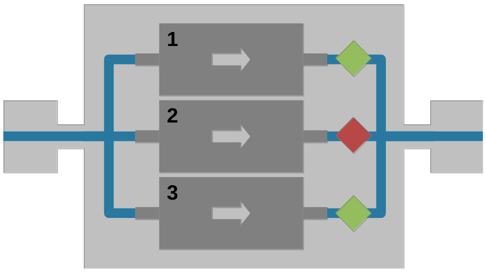
- If the electronic is designed to control the amplitude of each pump separately, it will be possible to have different amplitudes to the different pumps. Thus when a single pump loses some performance the amplitude can be raised accordingly, see Figure 3 and Figure 4.

  However, this calls for a control method like flow rate measurement or other for each pump.



	normal mode		partial loss of pump performance		further loss of pump performance		before failure of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate
1	on	9%	on	9%	on	10%	on	10%
2	on	5%	on	10%	on	10%	on	100%
3	on	6%	on	9%	on	15%	on	15%
Resulting sum of flow rate is kept up!								

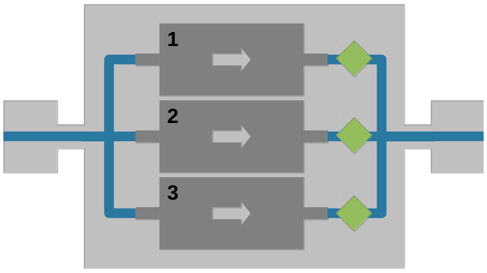
Figure 3: Parallel control of three pumps until failure of a single pump.



	partial loss of pump performance		further loss of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate
1	on	25%	on	25%
2	failure	0%	failure	0%
3	on	32%	on	40%
Resulting sum of flow rate is kept up!				

Figure 4: Parallel control of two pumps with increased amplitude after failure of one pump.

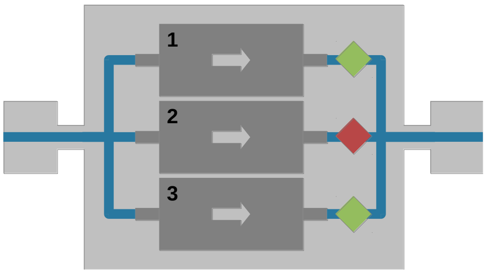
- The other solution is to control all pumps with the same amplitude. Hence, when one pump is losing some performance the amplitude for all pumps is increased a bit to compensate this loss, see Figure 5. When one is failing it will still be powered, unless there is some electronic procedure to switch it off. The amplitude for all pumps is raised further and the two remaining pumps have to compensate, see Figure 6. With the flow measurement somewhere in the flow line this will be the simplest way of maintaining volume flow.



	normal mode		partial loss of pump performance		further loss of pump performance		before failure of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate	state	amplitude for flow rate
1	on	5%	on	9%	on	15%	on	25%
2	on		on		on		on	
3	on		on		on		on	
Resulting sum of flow rate is kept up!								

Figure 5: Parallel control of three pumps with one amplitude for all.

The blue marked fields represent pumps that suffer some loss. The red text should indicate an imminent failure.



	partial loss of pump performance		further loss of pump performance	
pump	state	amplitude for flow rate	state	amplitude for flow rate
1	on	37%	on	42%
2	failure		failure	
3	on		on	
Resulting sum of flow rate is kept up!				

Figure 6: Parallel control of three pumps with one amplitude for all.

After one pump failed the amplitude is increased for all, so that remaining pumps can compensate. Then the two remaining pumps have to compensate further losses.

Why does lower amplitude increases life time?

The lower amplitudes mean that the piezo actuators inside the pumps will see much lower electrical and mechanical loads. Especially the alternating mechanical load will be reduced, which has a huge impact on the thin piezo ceramic layer.

Why flow rate measurement?

Keeping up the flow rate (or the pressure generation) is mostly the desired goal. If some electronic has to change the amplitude of the pumps it requires some means to decide when this has to be done. The flow measurement (or pressure measurement) can be easily applied in a closed loop control.

A simple flow measurement can be made out of two pressure sensors and a restrictor.

All values are approximate and no guarantee of specific technical properties.

Changes in the course of technical progress are possible without notice.

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