Presentation

Reducing the wall thickness of cups and pistons in floating cup pumps and motors

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INNAS

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Mrs. Chairman, ladies and gentleman, good morning.

Or, should I say: ‘good afternoon’ or ‘good evening’?

This is a pump we recently replaced in one of our test benches.

A closer look reveals that this pump has not been produced by Bosch Rexroth. It has not even been produced by Mannesmann Rexroth. It has been produced by Rexroth, before it became a part of Mannesmann, and, later on, of Bosch.

Do you also see the name in the lower left corner? It says ‘Hydronorma’, a brand that Rexroth only used 50 to 60 years ago. Which means, that this pump is at least 50 years old.

But then our pumps.… They stayed the same in the past fifty years.…

Well…the colour has changed.

Why is this wrong?

But, why is this wrong? Or, is it wrong at all?

no, it's not wrong…

- to be prudent and conventional
- to be proud of your products
- to ignore the shifting needs in society

No, it's not necessarily wrong.

- There is nothing wrong with being prudent and conventional.
- There is also nothing wrong with being proud of your own products, especially when they are so robust that they still perform after 50 years.
- It is even not wrong to ignore the changes in society and the resulting shifting needs of your customers. At least not as long as you make this the choice to do so. Deliberately and consciously.

For those of you who want to innovate

But, for all of you who are not content with a status-quo. For all of you who want to innovate, I have good news.

chances and opportunities

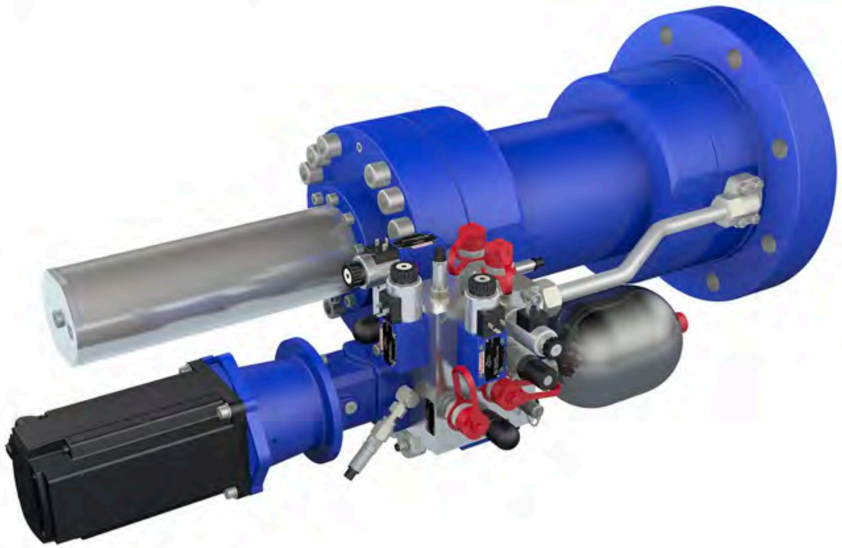
- power management
- increased power, force and torque density
- higher efficiency
- lower cost
- robotics, Industry 4.0, IoT

There are plenty of chances and opportunities:

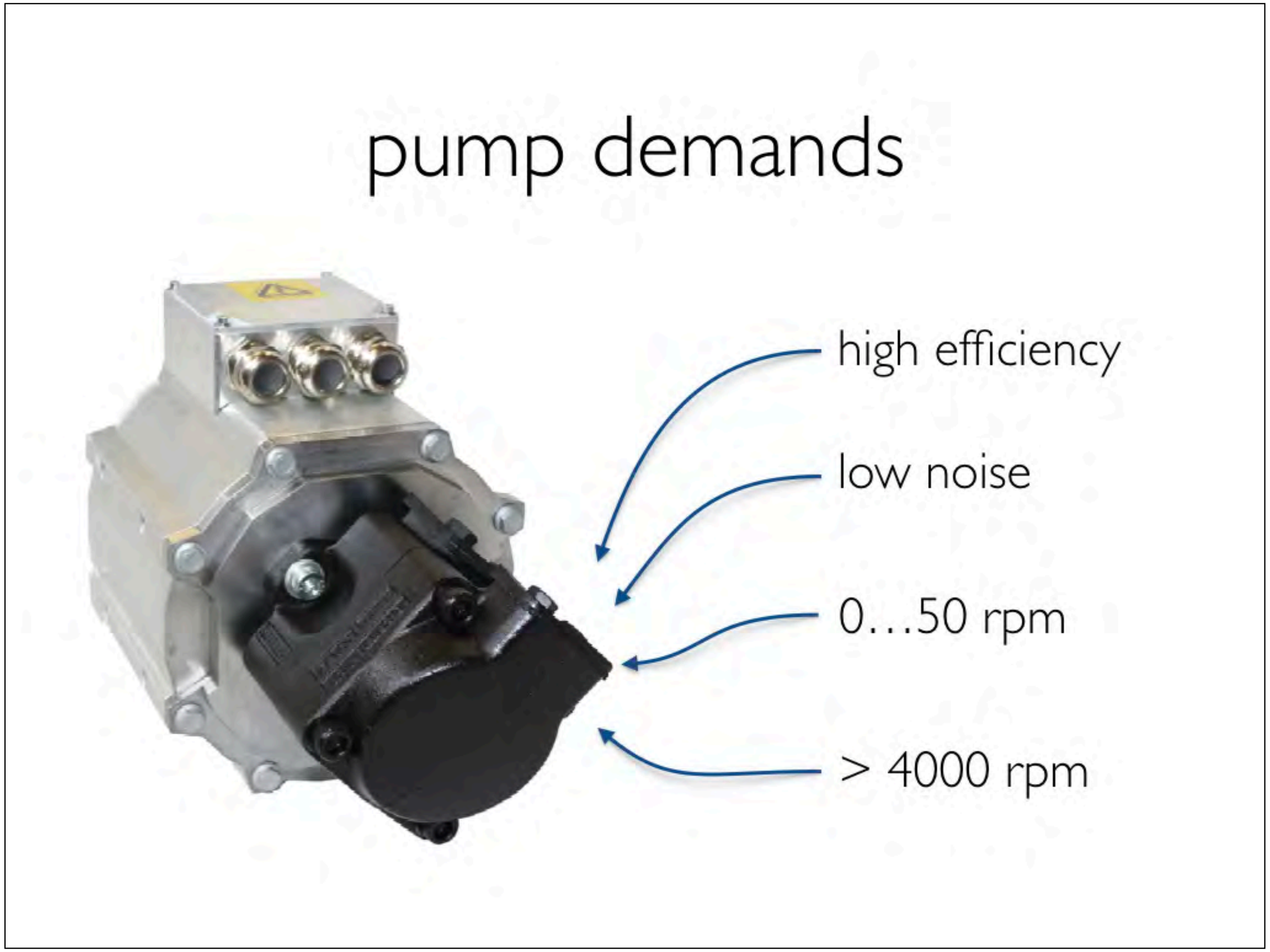
- Hydraulics are perfect for power management;
- The power, force and torque density is still unparalleled and can even be further increased;
- It is equally necessary and possible to reduce the costs of hydraulics;
- Finally, we can and will play a vital role in important topics as robotics, Industry 4.0, and the Internet of Things.

Let me give you an example

electro-hydraulic actuators

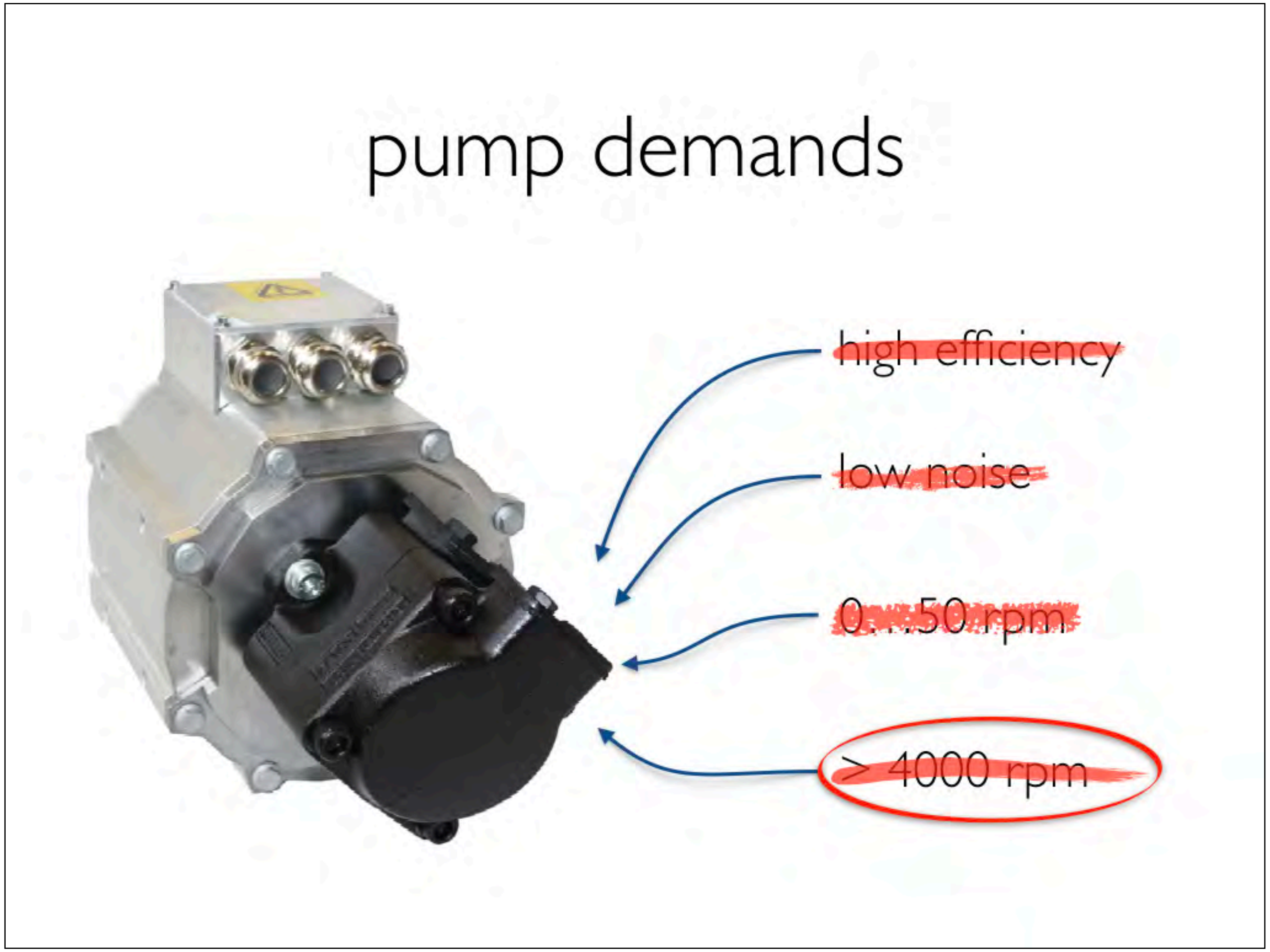


These electro-hydraulic actuators are a hot topic nowadays. A speed controlled electric motor directly controls the speed and displacement of this hydraulic cylinder



But, these markets, and these new applications set new demands for hydraulic pumps:

- They need to be efficient…
- …and the noise level should be low;
- Furthermore it has to be possible to run these pumps at low operating speeds, close to zero rpm,…
- …as well as at high operating speeds, above 4000 rpm.



And none of this is possible with current pumps.

Now, let's just have a closer look at the last point: why can't we make our hydraulic pumps and motors run at high speeds? Let's say, at 6000 rpm?

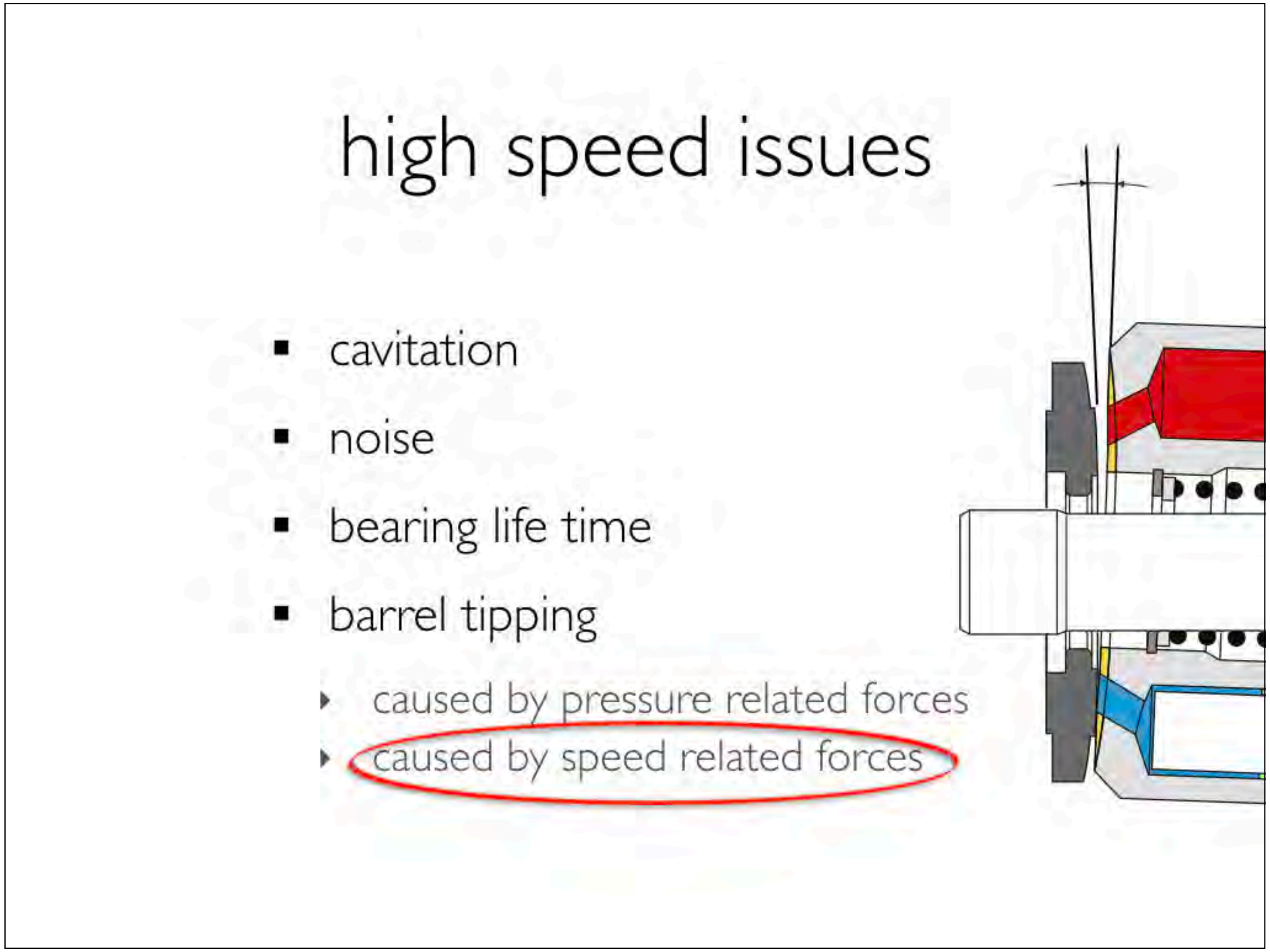
challenges for achieving a high pump speed

What are the challenges for achieving a high speed?

high speed issues

- cavitation
- noise
- bearing life time

- of course, for pumps, cavitation is strong speed limiting factor
- so is noise…
- …and bearing life time

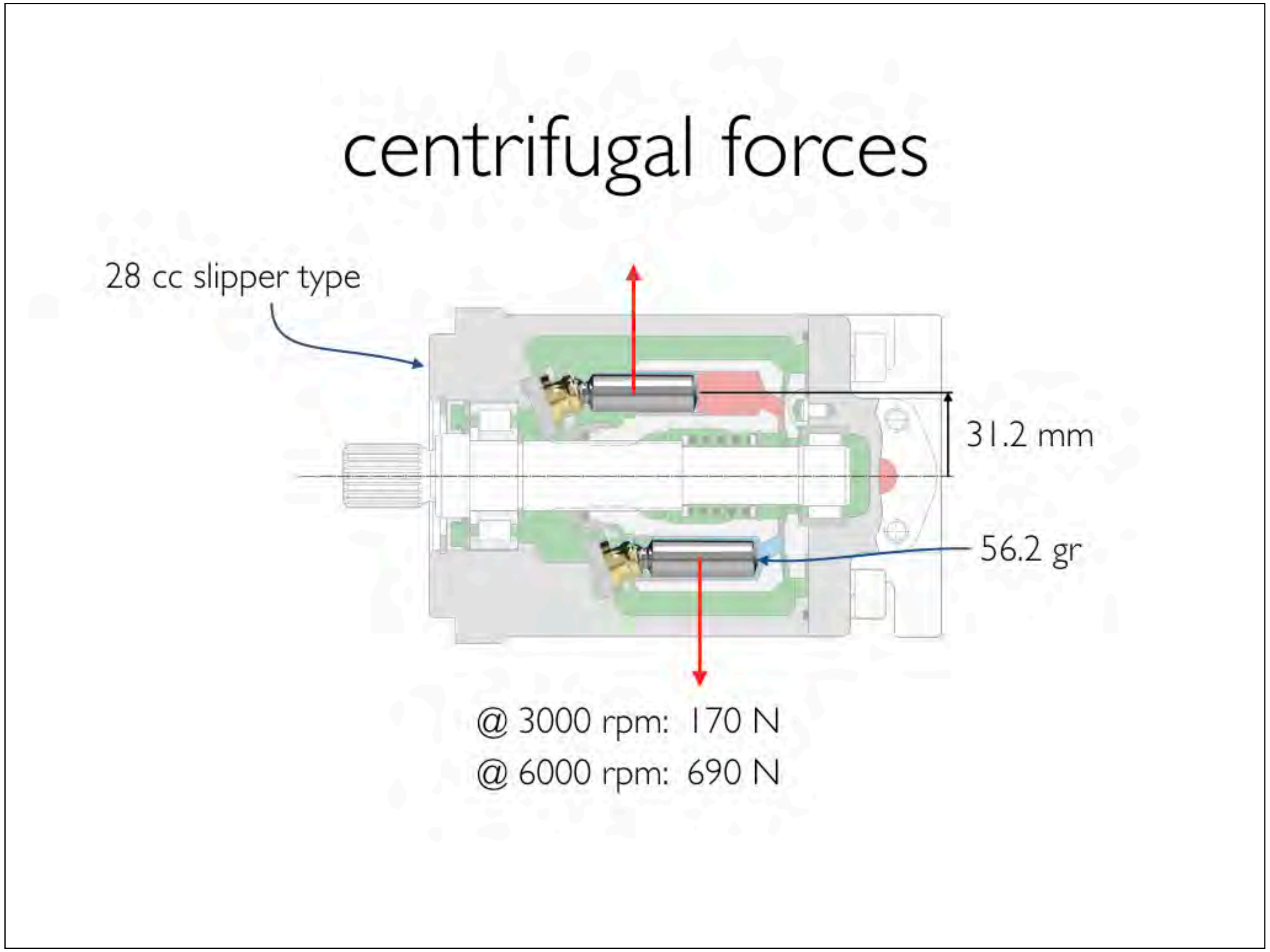


And then, there is this phenomena called ‘barrel tipping’. It happens when the barrel can no longer be pushed against the surface of the port plate.

There are two groups of forces that can create barrel tipping:

- pressure related forces
- and speed related forces

In this presentation I will concentrate on the last category: the speed related tipping torque



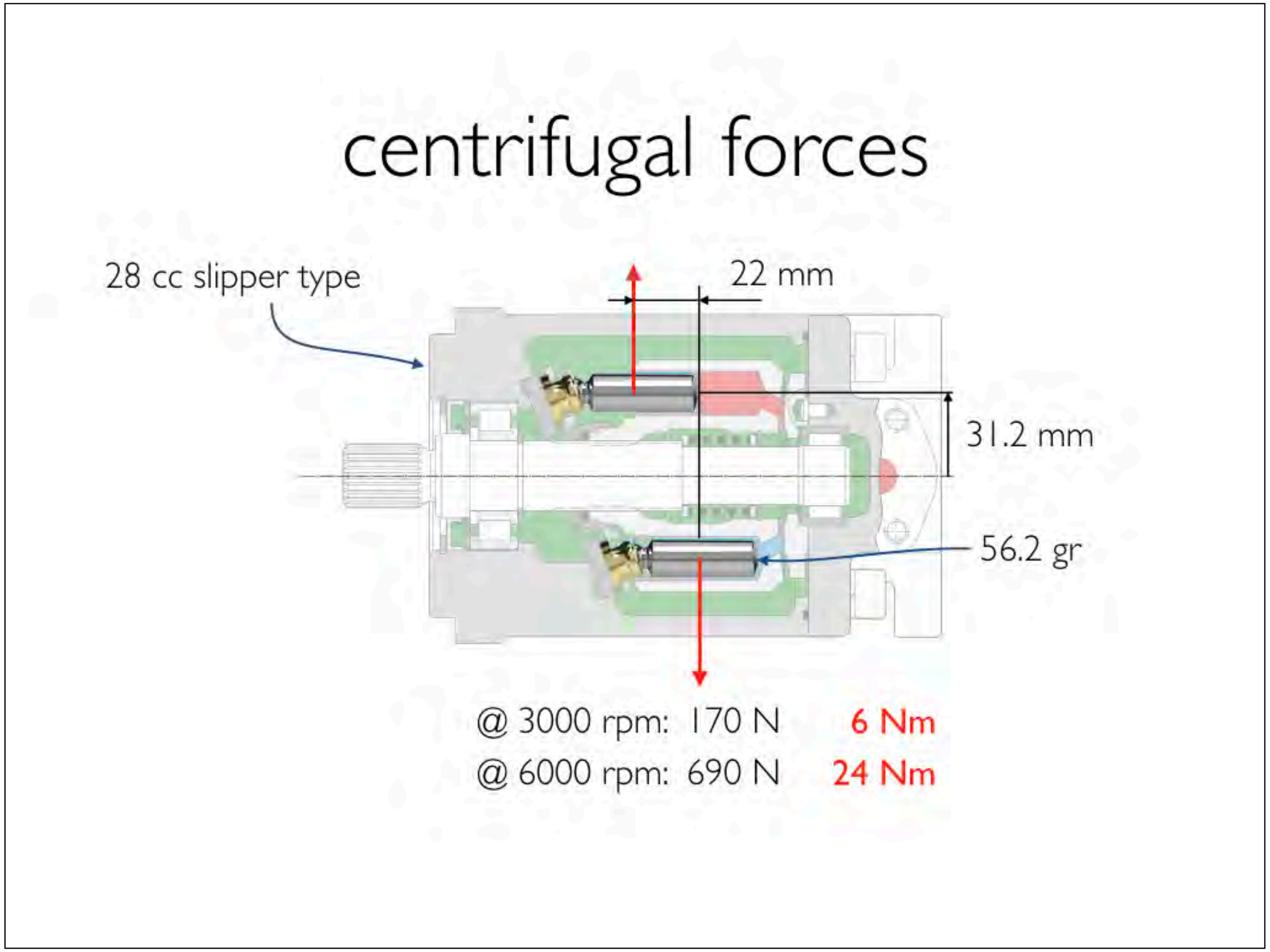
Let me explain this to you, using this small fixed displacement machine as an example.

The piston weighs a little bit more than 56 grams.

Giving the dimensions of the cylinder barrel, we can calculate the centrifugal force of a single piston.

At a rotational speed of 3000 rpm, this force amounts to 170 N. Which means that this small piston of 56 grams, has the equivalent weight of 17 kg at 3000 rpm.

At 6000 rpm, the force is 4 times a high and becomes 690 N, which corresponds to the weight of an adult person.

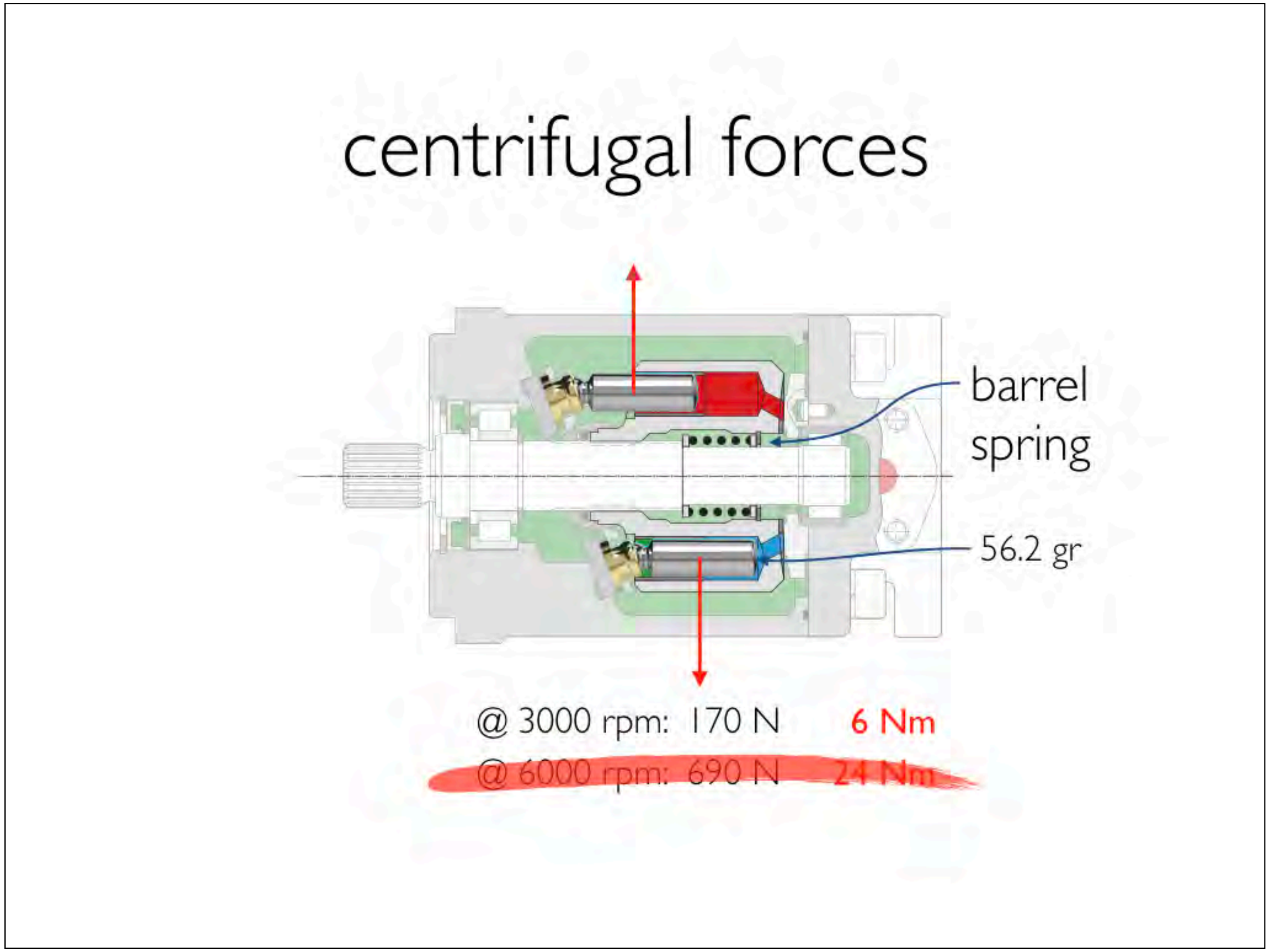


Since the piston position varies while the barrel rotates, the centrifugal forces of the pistons are not in line. They therefore create a torque load on the barrel.

At 3000 rpm, the total torque load of the centrifugal forces of 9 pistons amounts to 6 Nm.

At 6000 rpm, this load is increased to 24 Nm.

The torque load could –to some extend– be counteracted by hydrostatic forces.



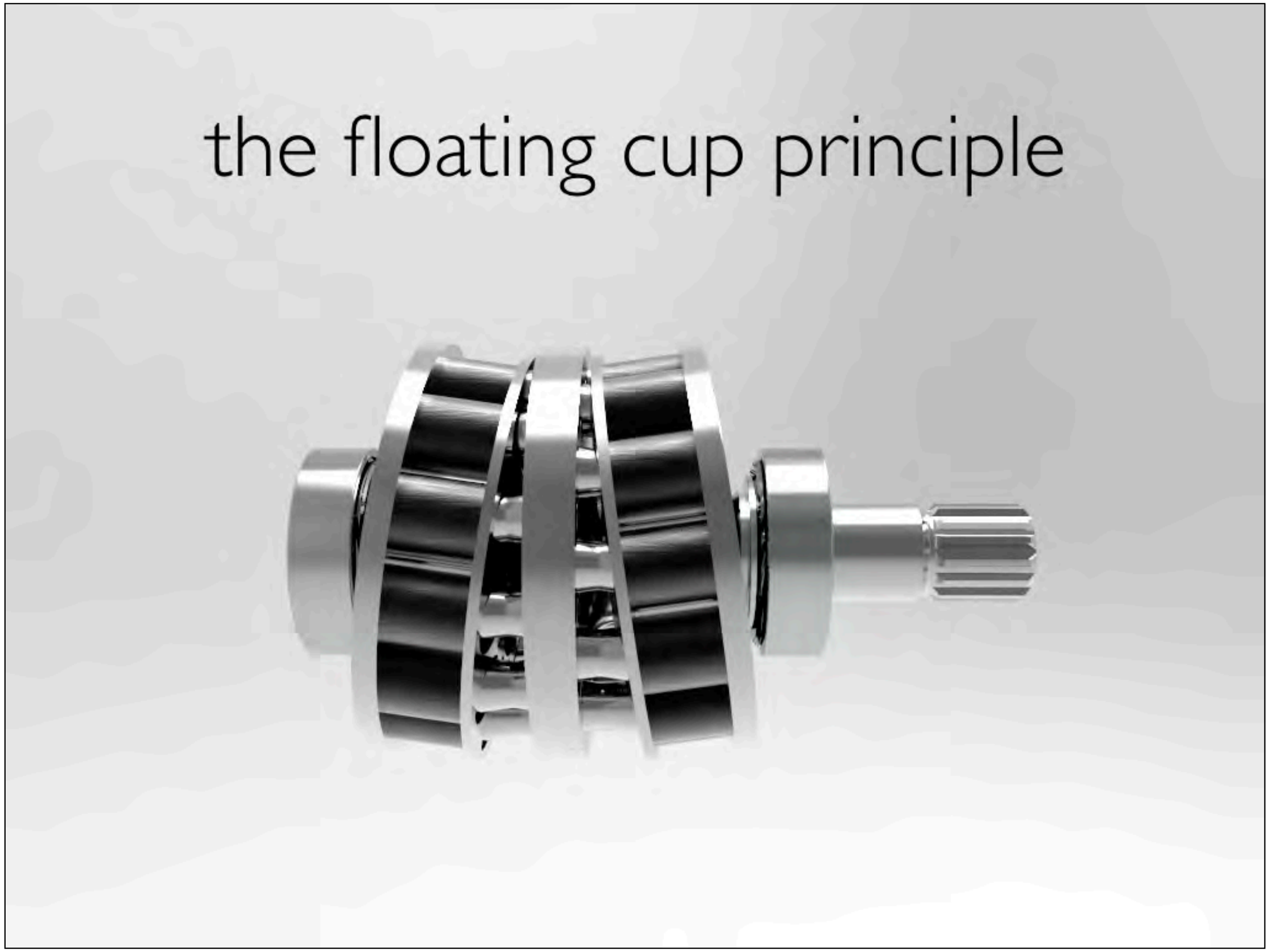
But, if we consider a low pressure level, then only the central barrel spring can push the barrel on to the port plate. This force is strong enough to make the pump run at 3000 rpm.

But it can not counteract the centrifugal tipping torque at a rotational speed of 6000 rpm.

This is probably the reason why I sometimes hear experts say that you can not make these pumps run at high speeds.

a fundamental problem
demands a fundamental solution

Yes, this is a fundamental problem. A fundamental problem that demands a fundamental solution.



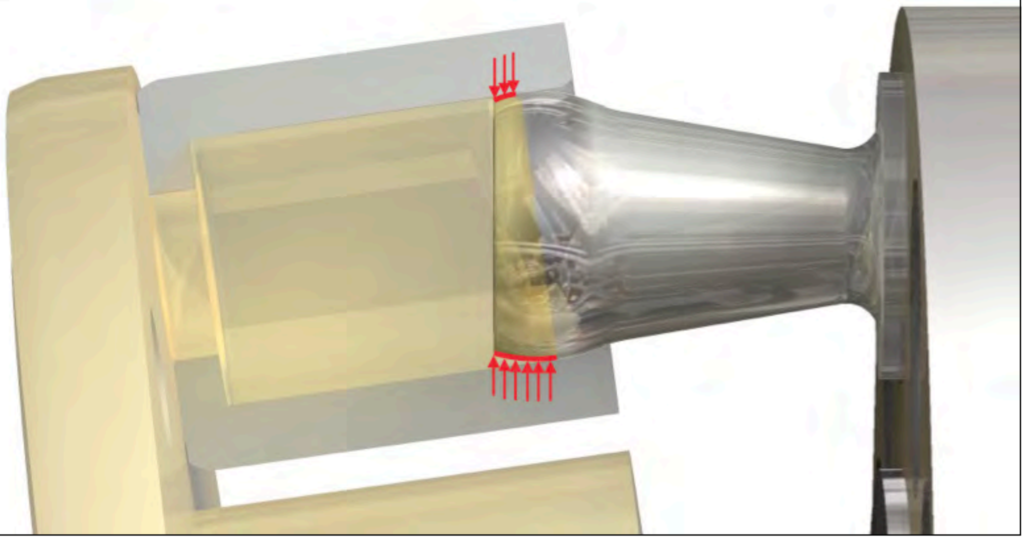
Our floating cup principle is such a fundamental solution.

This new principle offers some advantages, which are of great importance for the application in electro-hydraulic actuators.

The floating cup principle is a multi piston principle, which helps to reduce noise levels

characteristics

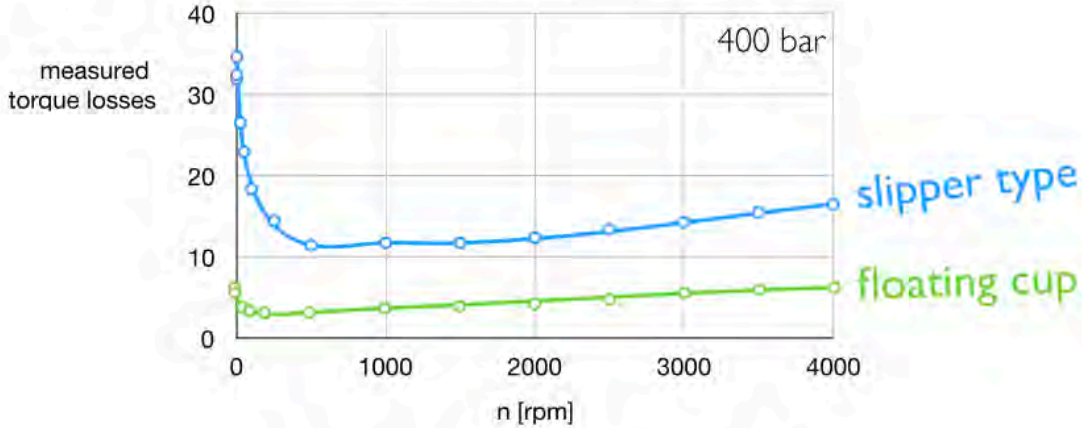
- low noise level
- high efficiency



It is efficient, featuring a direct conversion from pressure forces to torque, and vice versa.

characteristics

- low noise level
- high efficiency
- no minimum speed limitation

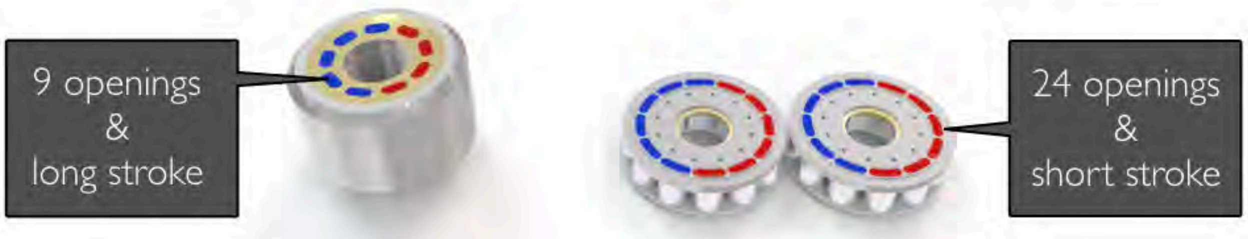


Slipper type machines can’t run at low rotational speeds because the friction and wear become to high. These are measurements we recently performed at our new test bench. The test of the slipper type pump shows the typical Stribeck-curve, with a strong increase of the friction close to zero rotational speeds.

Floating cup machines don’t have this limitation. Even at close to zero speed, the friction torque is lower than the lowest value of the slipper type machine.

characteristics

- low noise level
- high efficiency
- no minimum speed limitation
- large opening areas of the barrel ports



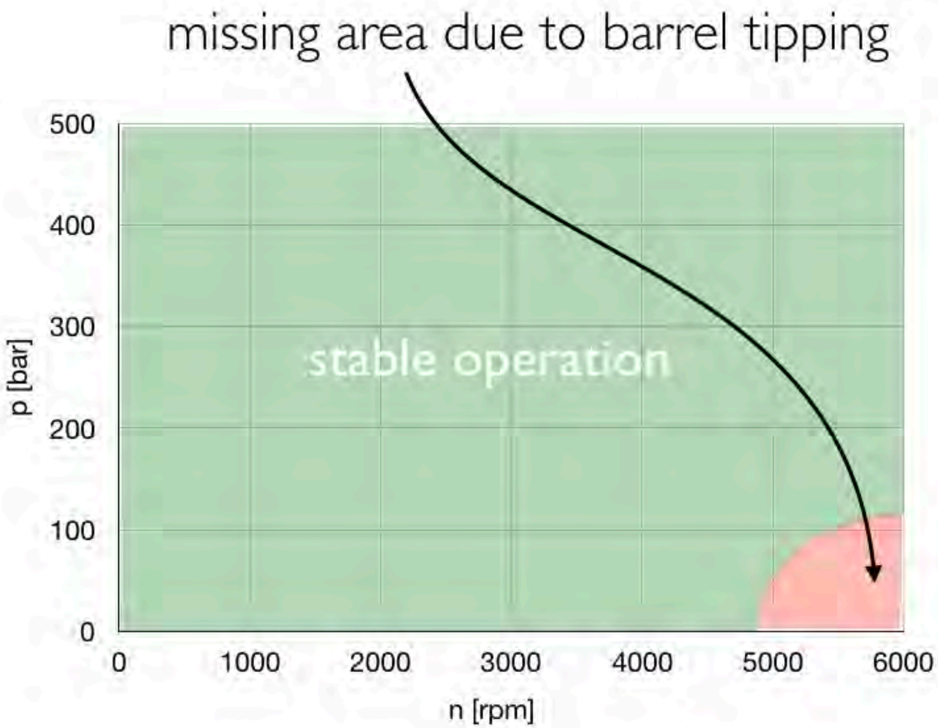
The floating cup principle also has a much larger number of barrel ports. Combined with a much shorter stroke, this strongly reduces the risk for cavitation.

characteristics

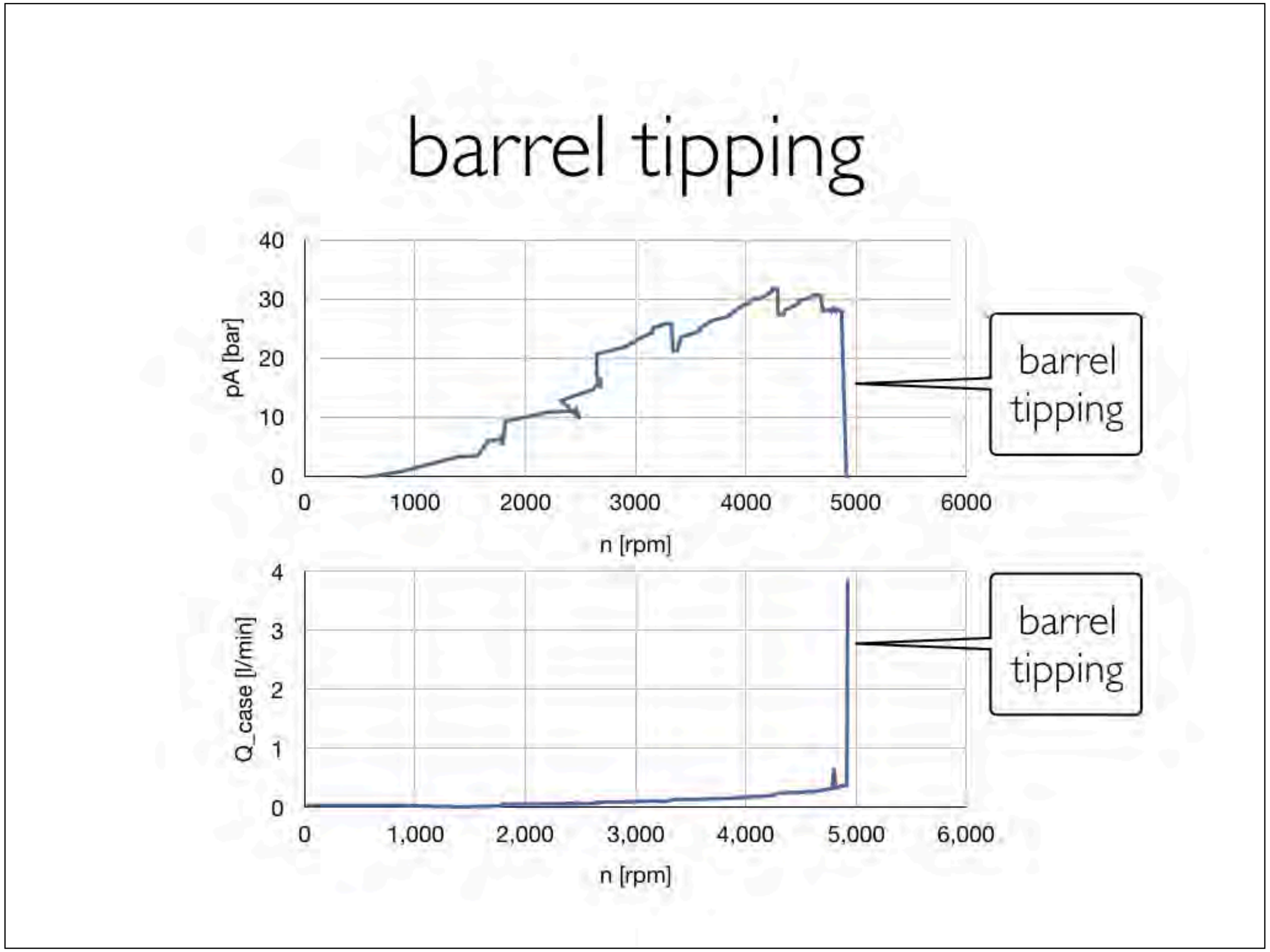
- low noise level
- high efficiency
- no minimum speed limitation
- large opening areas of the barrel ports
- low centrifugal forces

Finally, the centrifugal barrel torque is much lower in floating cup machines. This is partly due to the short stroke length, but the most important factor is the low mass of the cups.

limited field of operation



Nevertheless, we found an area in the field of operation where the pump could not be operated due to barrel tipping.



These two graphs show what happened at high operating speeds and low pump pressures. At around 4900 rpm, the pump pressure suddenly dropped to zero. At the same moment, the case drain flow went through the ceiling.

port plates after barrel tipping

When we opened the pump after this experiment, we saw a marking of the barrels, on both port plates. The marking was at the same location. Please consider that the two port plates are mirrored.

stronger barrel spring?

The most obvious solution for this problem is to increase the strength of the barrel springs.

Like in the other axial piston pumps, a spring is used to push the barrel against the port plate. But it is a light spring, about a quarter of the strength of springs in other axial piston machines. So, why not choose for a stronger spring?

disadvantages of a stronger spring

- increased contact force between barrel and port plate
- increased friction losses, especially at low rotational speeds
- increased wear

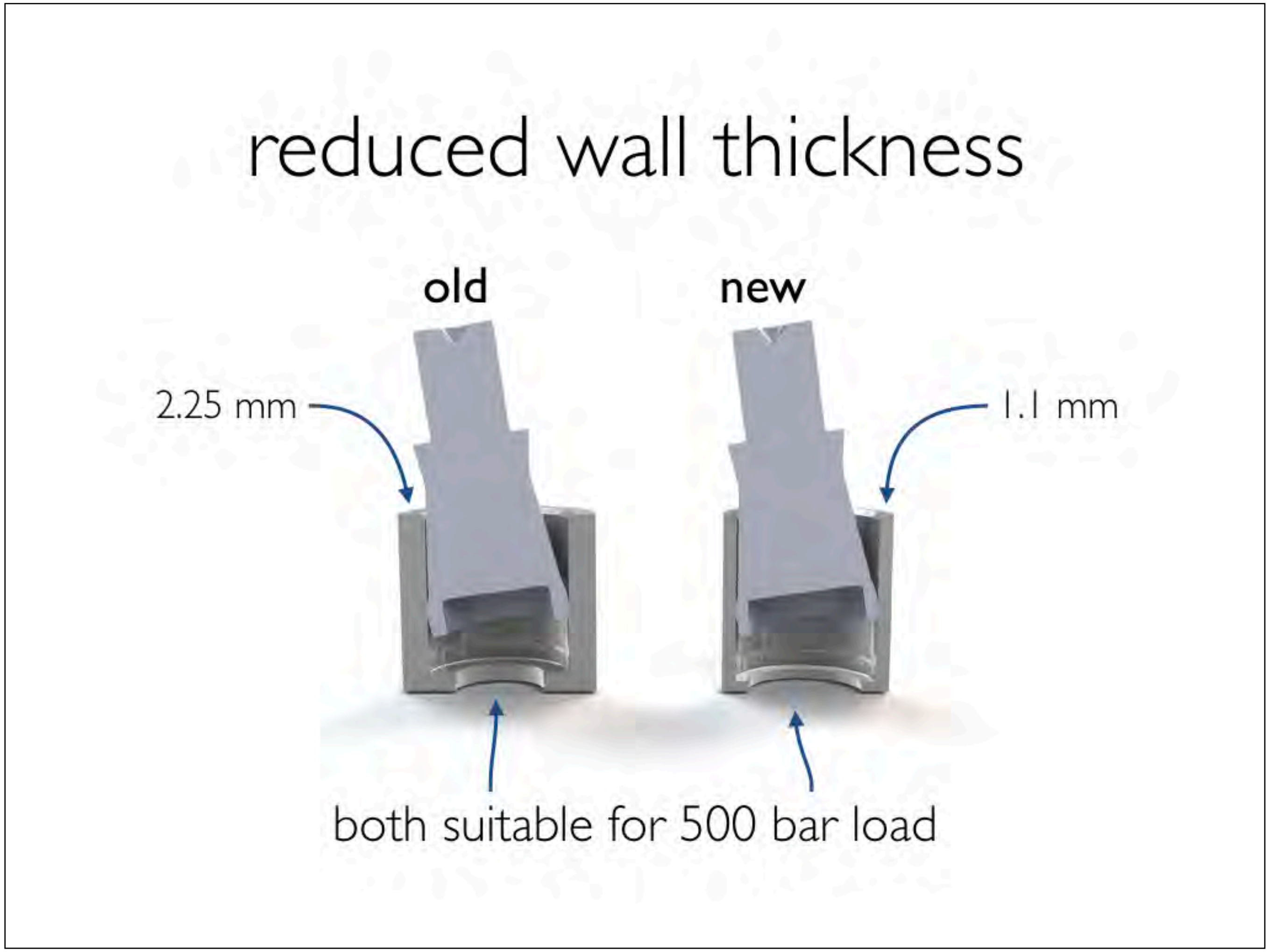
There is a simple reason:

- A stronger spring increases the contact force between the barrel and the port plate;
- This will result in a reduction of the efficiency
- and an increased wear

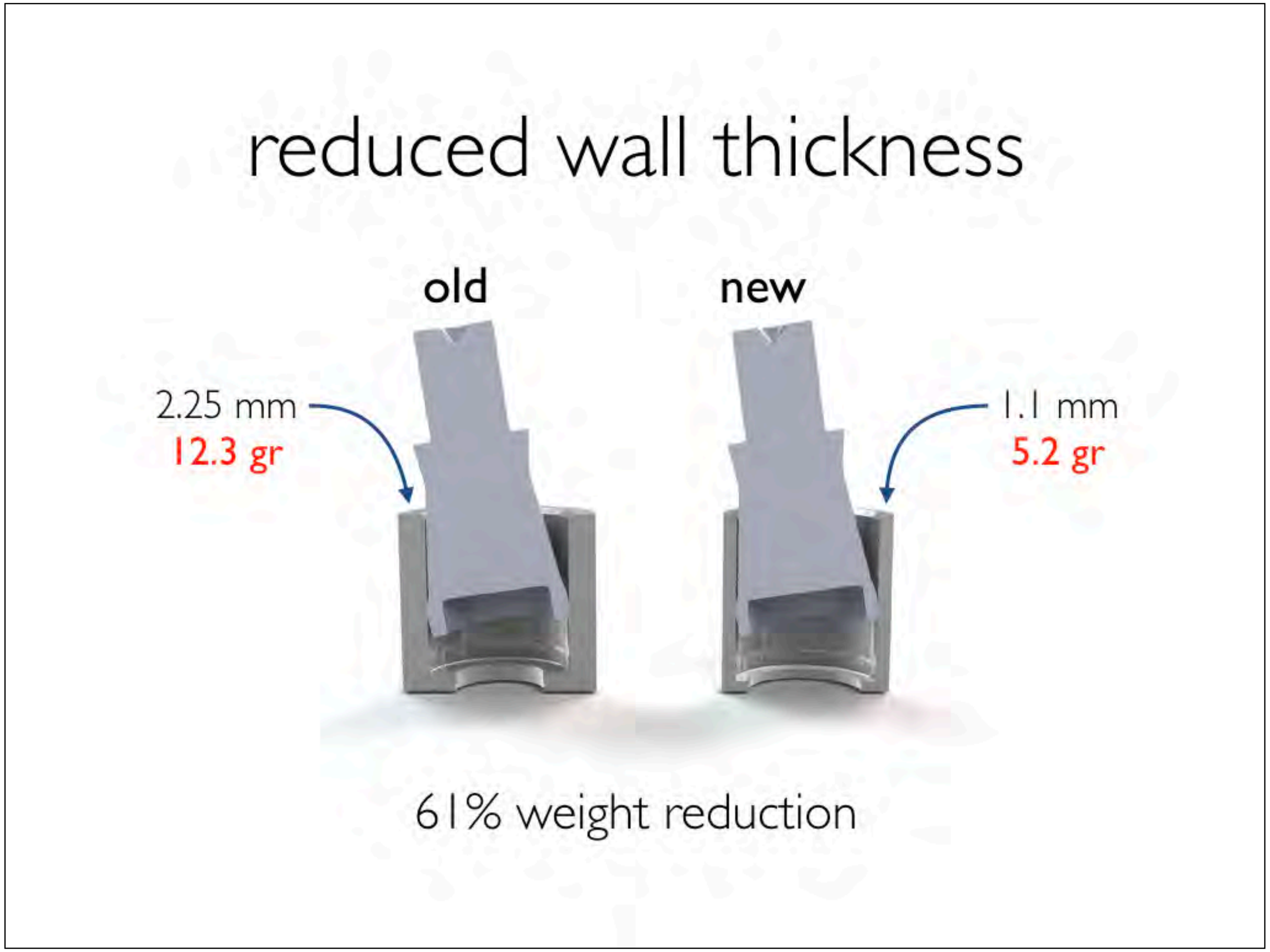
For us, this is a no-go-area

Reducing the cup mass

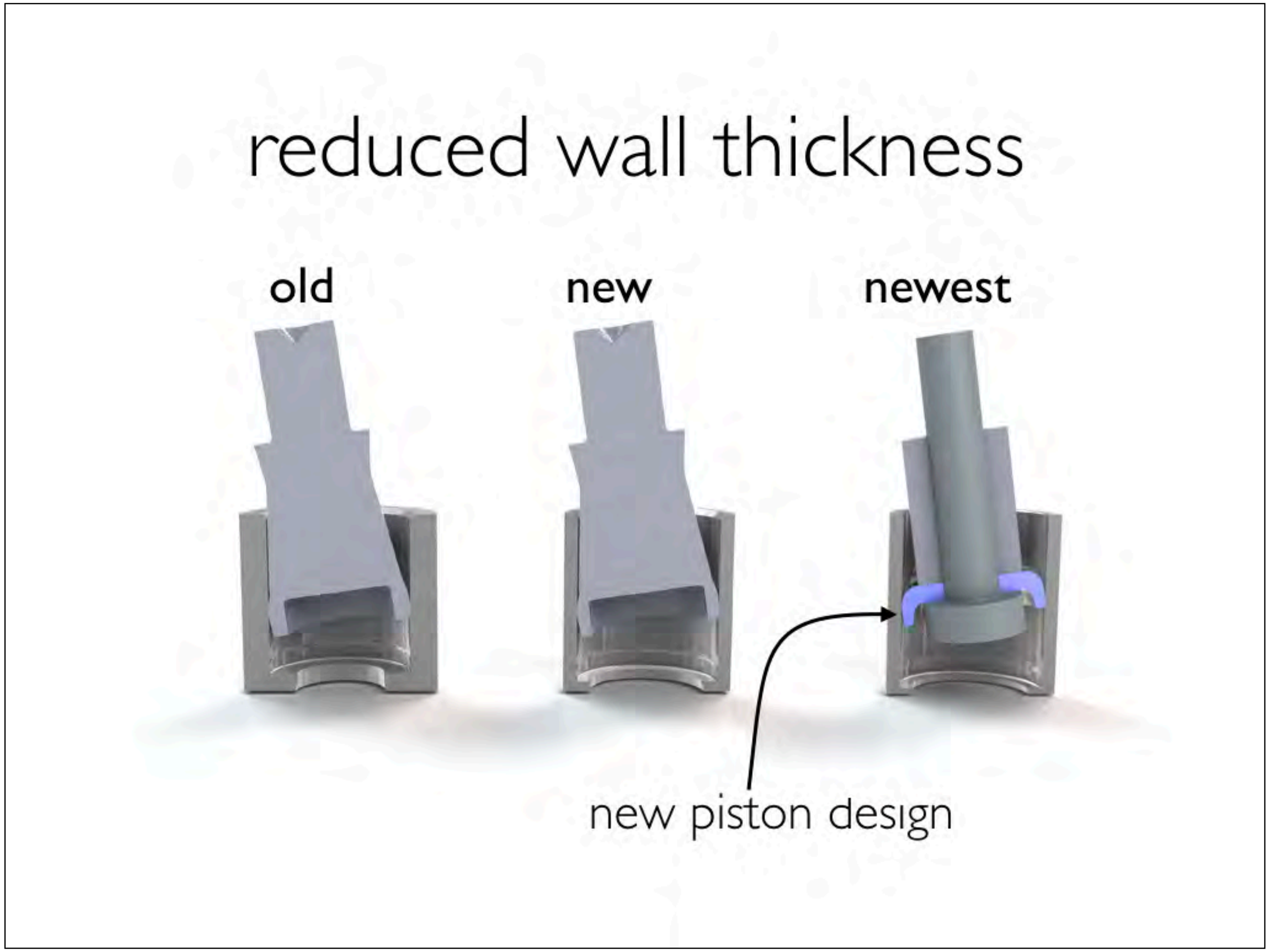
In order to solve this issue we decided to reduce the mass of the cups, by reducing the wall thickness of the cups.



Here you see the old design and the new design. The wall thickness has been reduced by a factor of two. Nevertheless, the new design can still be operated at a rated pressure of 500 bar.



We managed to reduce the weight by as much as 61%. The cup mass is now reduced to 5.2 gram. With this mass reduction, we can now operate the pump in the entire field of operation.



The new cup design also allows us to apply low cost production technologies, like deep drawing and stamping.