

Presentation

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

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



I N N A S

Peter Achten  
March 20, 2018

Mrs. Chairman, ladies and gentleman, good morning.

Or, should I say: 'good afternoon' or 'good evening'?



'Time', ladies and gentleman, 'Time is an illusion'. That's what we learned from Albert Einstein.



Recently, scientists discovered that time, absolute time, even does not exist at all. But of course, we, living in the hydraulic community, we knew this already.



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.



in 50 years...

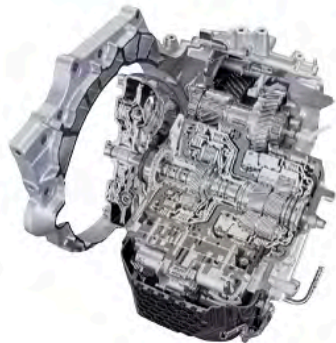
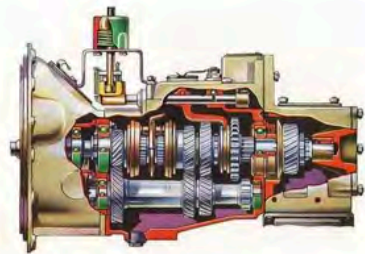


Now...in 50 years, we have seen many changes.

- Our phones have been transformed beyond recognition.
- Our TV-sets have become ultra-thin, colorful, multimedia, internet devices.
- Our cars still have 4 wheels, ...but that's about the only thing that hasn't changed.



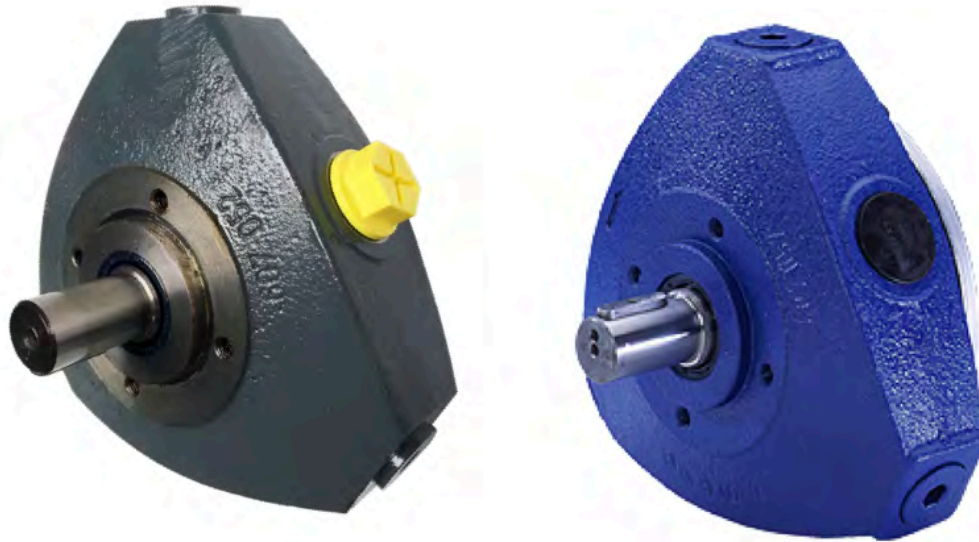
in 50 years...



- In 50 years, gear transmissions have changed,
- washing machines have been revamped,
- and even our prams, or 'Kinderwagen', have been completely redesigned.



in 50 years...



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.



Like every Amish boy and girl has to do when they become 18. I have a deep respect for the Amish people and the choices they make. They are known for simple living, plain dress, and reluctance to adopt many conveniences of modern technology.



Some of the Amish even don't use any motorized vehicles, and drive around in their horse-driven buggy's.

On the road, the two parts of society meet:

- the slow speed buggy's of the Amish,
- and the fast speed cars of the rest of the world.





And thus, you can find these kinds of traffic signs in the US, warning us for slow Amish buggy's on the road for the next 18 miles.



In a similar way, I suggest that we should also put a sign like this at the entrance of our conferences. A sign that warns the visitors and participants of this conference that they might stumble on some hydraulic technologies during their stay.

Hydraulic technology which has been standing still for the past 50 years, and might continue to do so for the next 18 years. The sign should be a warning for all visitors, which are coming from other disciplines, and are moving on the fast lane of technology development.

And while we are at it, ...



...we might also start to wear hats and caps.  
And, of course, all men should  
grow a beard.

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

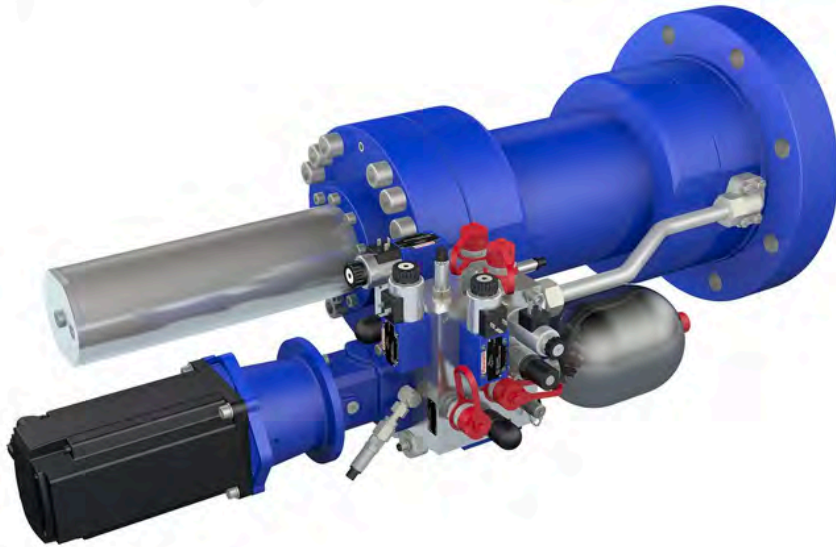
There are plenty of chances and opportunities:

- 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

# pump demands



high efficiency

low noise

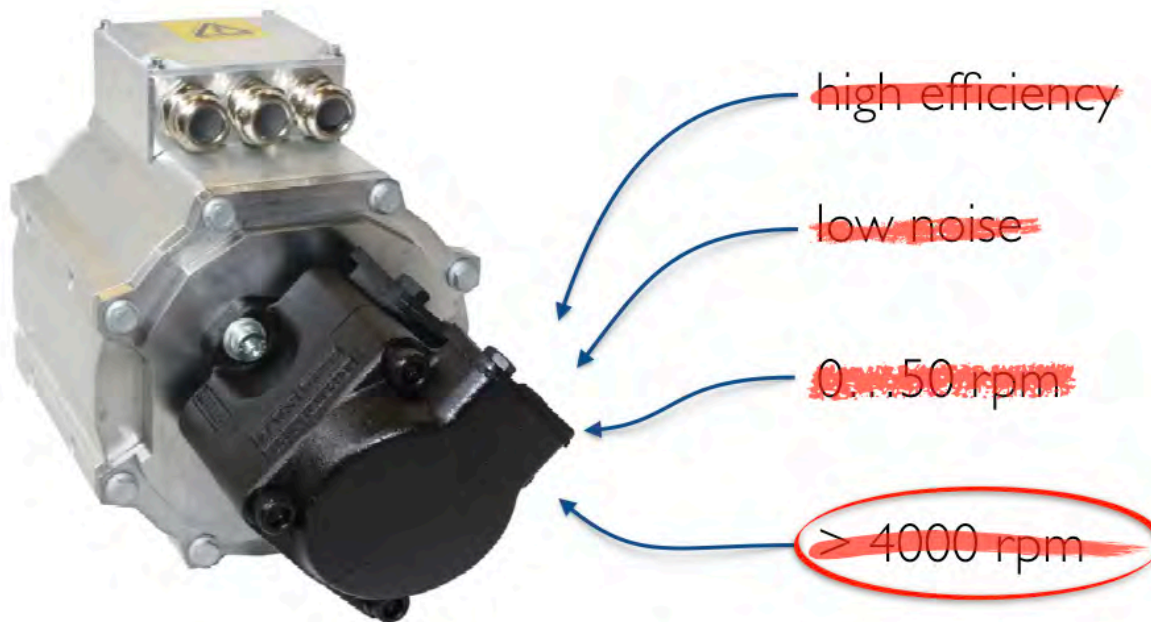
0...50 rpm

> 4000 rpm

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.

# pump demands



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

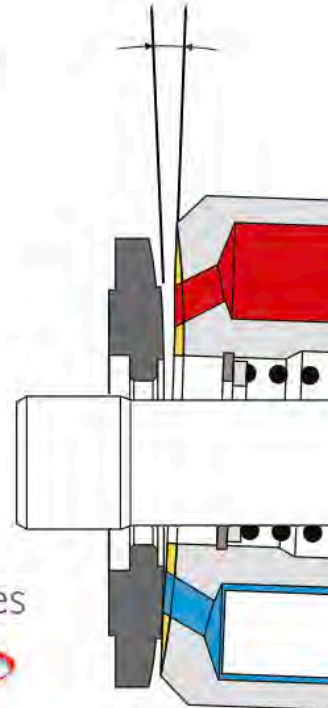
- cavitation
- noise
- bearing life time

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



# high speed issues

- cavitation
- noise
- bearing life time
- barrel tipping
  - ▶ caused by pressure related forces
  - ▶ caused by speed related forces



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.

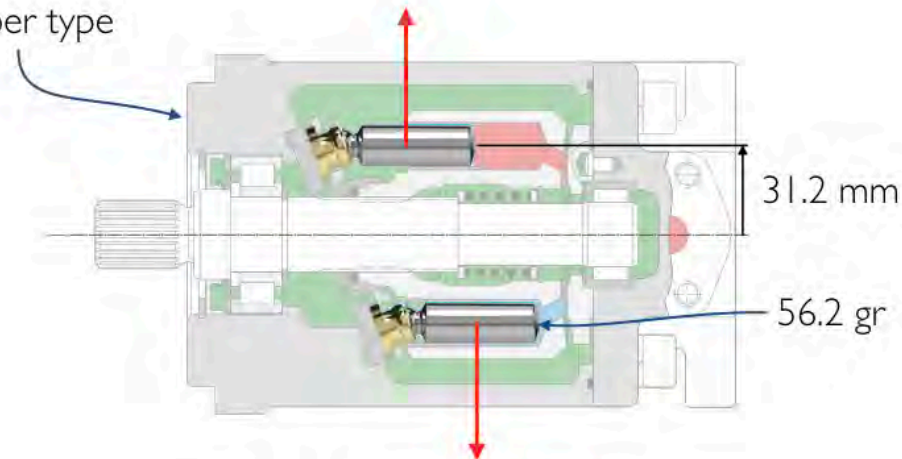
There are two groups of forces that can create barrel tipping:

- pressure related forces
- and speed related forces

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

# centrifugal forces

28 cc slipper type



@ 3000 rpm: 170 N

@ 6000 rpm: 690 N

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

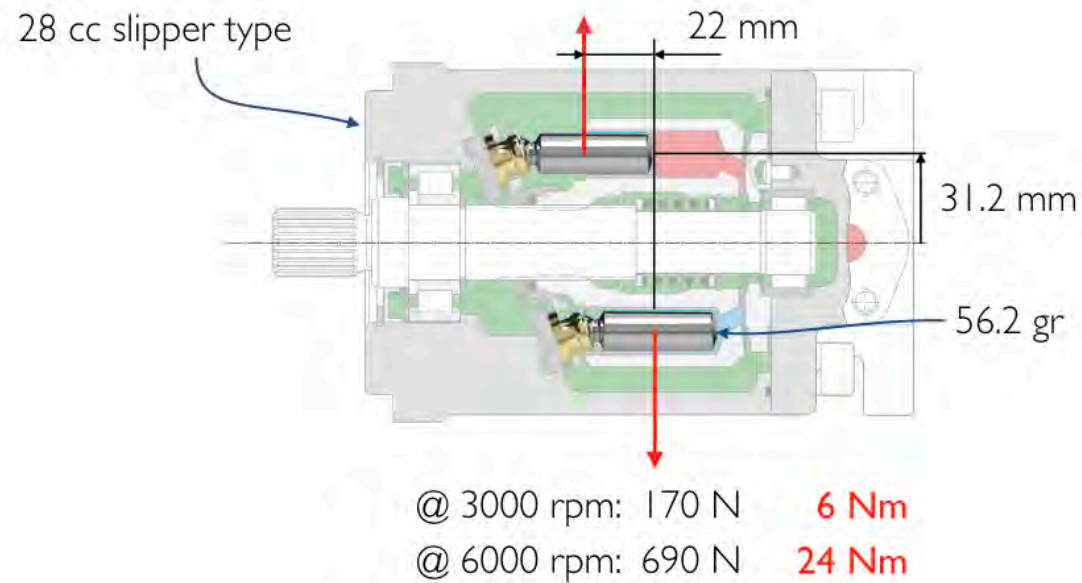
The piston weighs a little bit more than 56 grams.

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 as high and becomes 690 N, which corresponds to the weight of an adult person.

# centrifugal forces



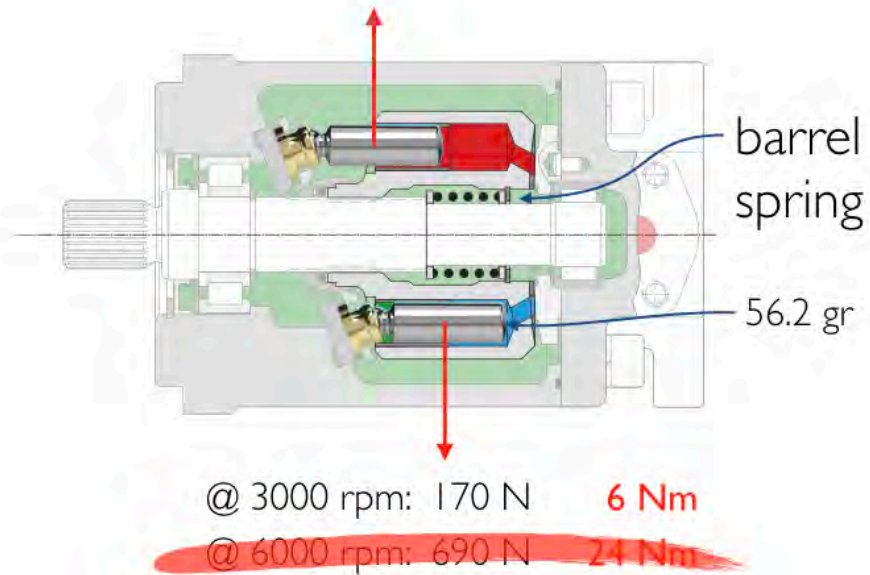
Since the piston position varies while the barrel rotates, the centrifugal forces of the pistons are not in line. They therefore create a torque load on the barrel.

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 extent– be counteracted by hydrostatic forces.

# centrifugal 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.



# the floating cup principle



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.

# characteristics

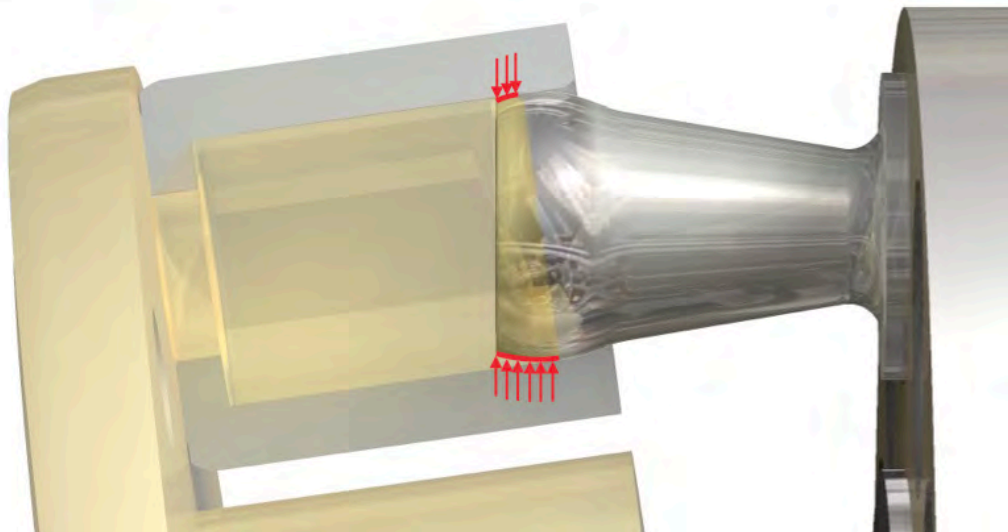
- low noise level



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

# characteristics

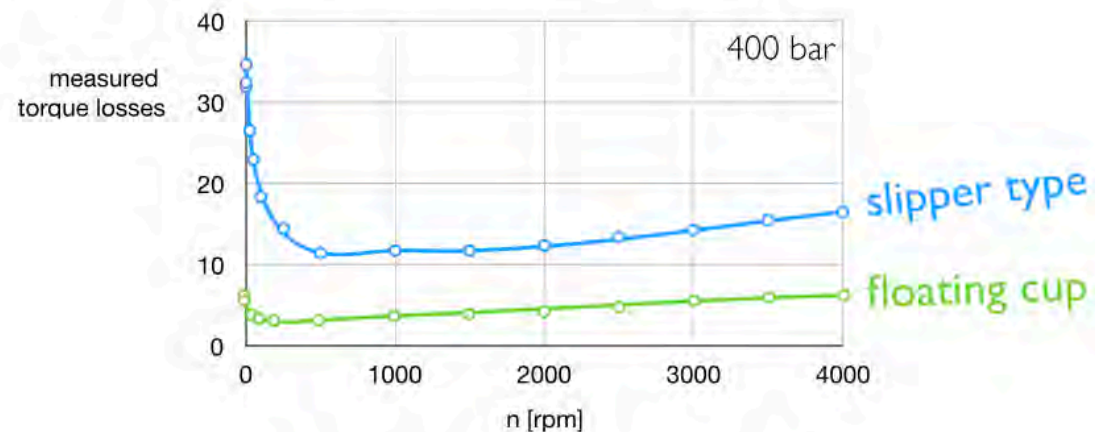
- low noise level
- high efficiency



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 too 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

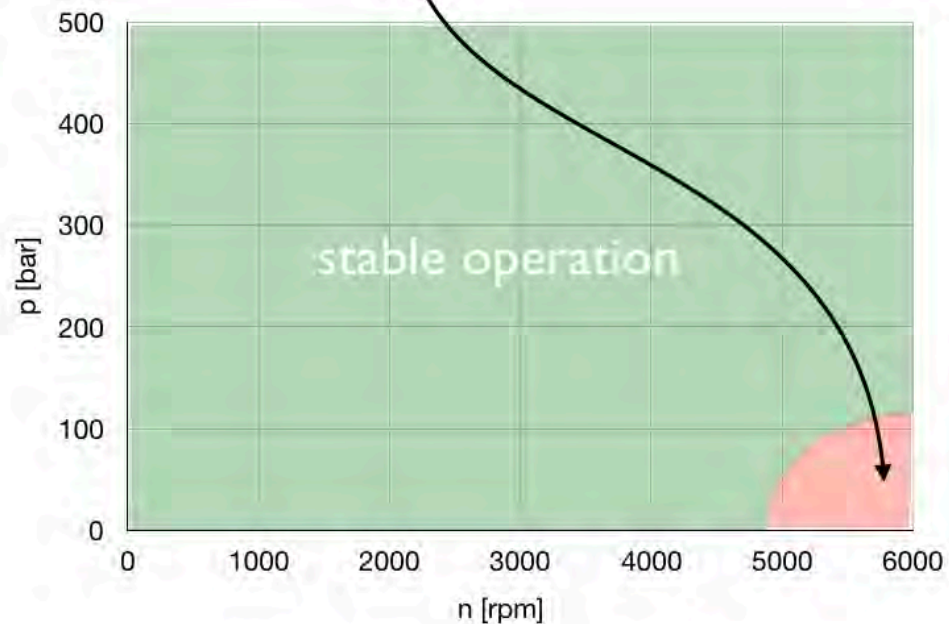


Finally, the centrifugal barrel torque is much lower in floating cup machines. This is partly due to the short stroke length, but the most important factor is the low mass of the cups.



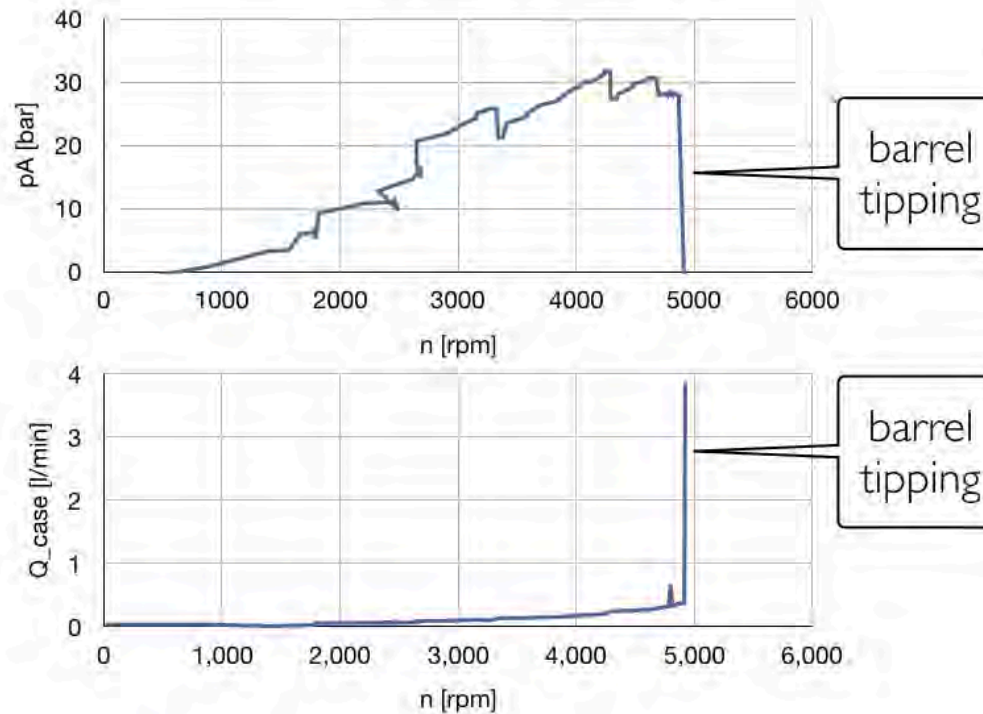
# limited field of operation

missing area due to barrel tipping



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

# 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.

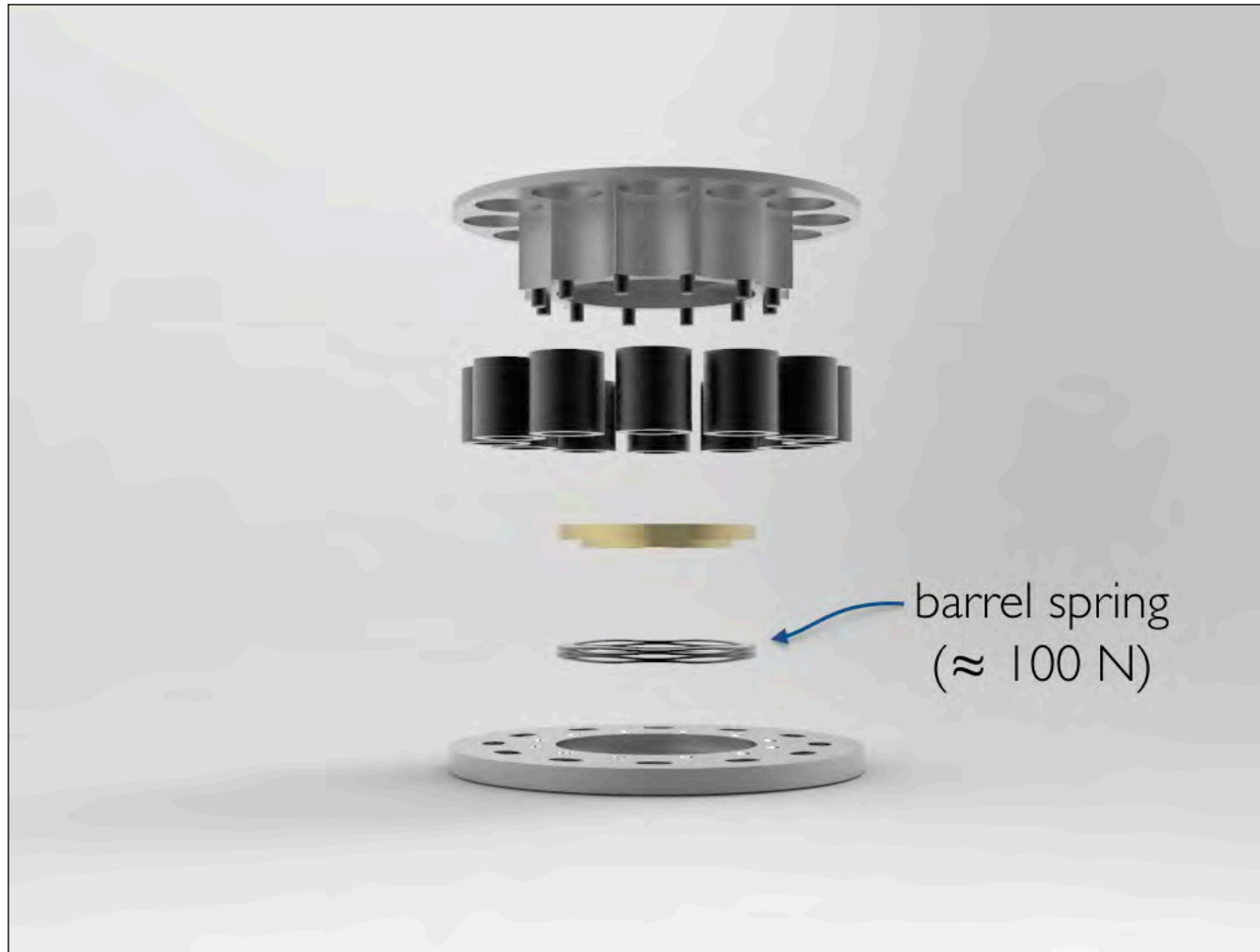
## port plates after barrel tipping



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

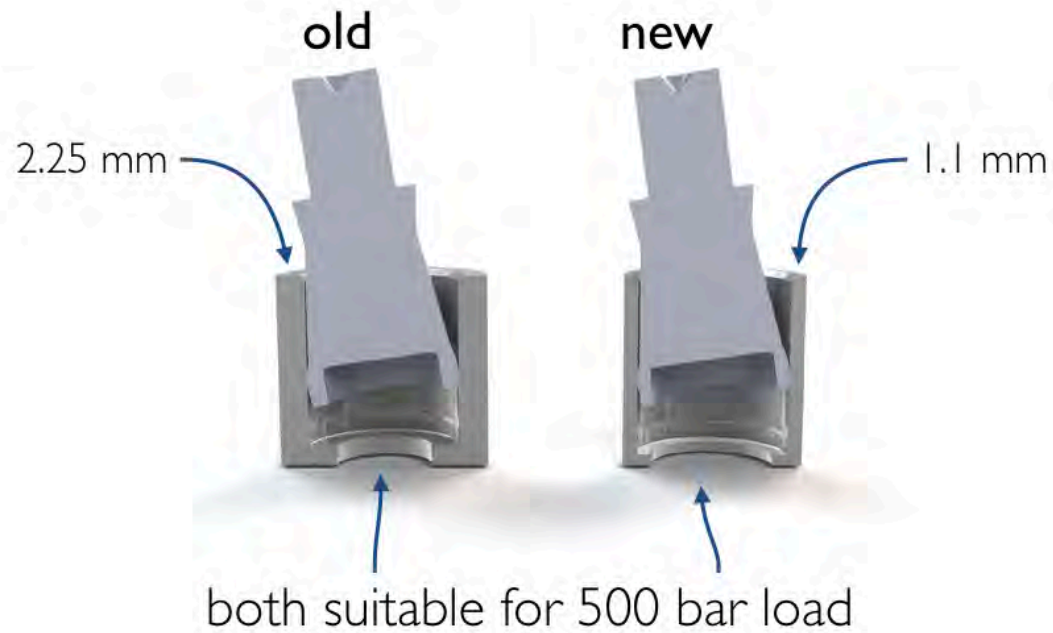
For us, this is a no-go-area



# Reducing the cup mass

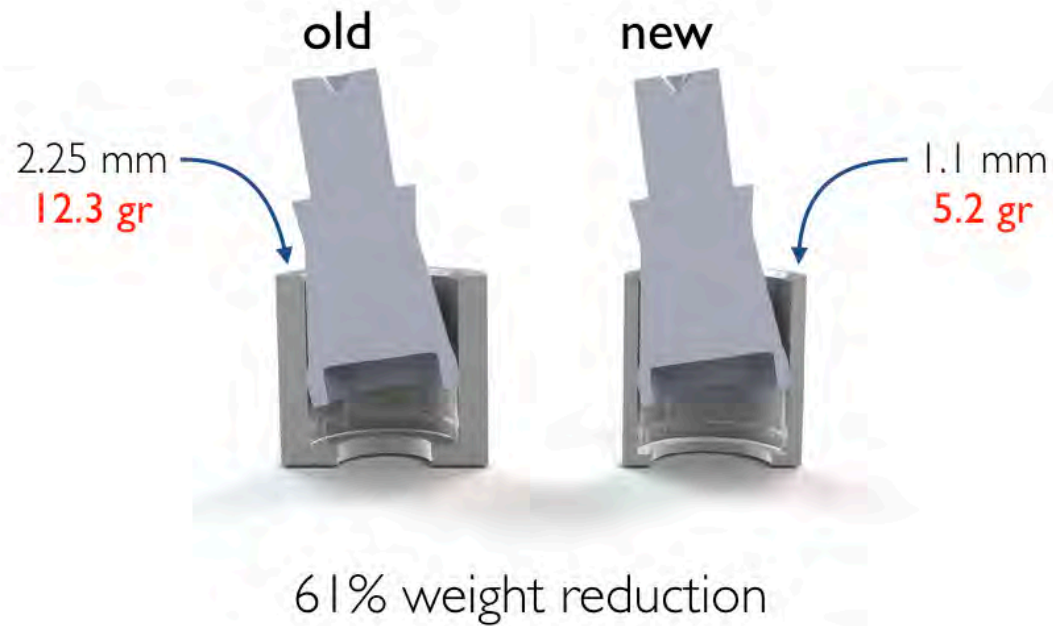
In order to solve this issue we decided to reduce the mass of the cups, by reducing the wall thickness of the cups.

## reduced wall thickness



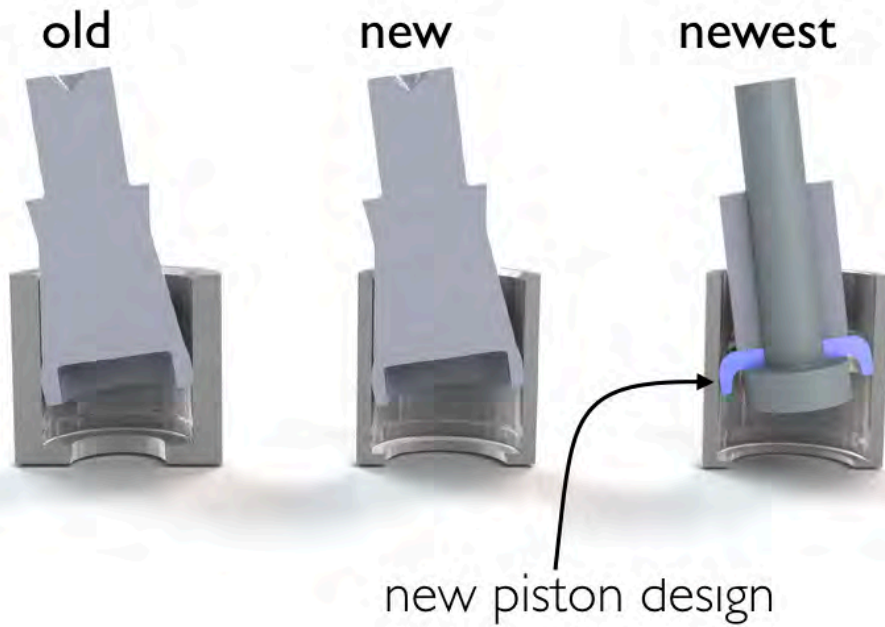
Here you see the old design and the new design. The wall thickness has been reduced by a factor of two. Nevertheless, the new design can still be operated at a rated pressure of 500 bar.

## reduced wall thickness



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.

## reduced wall thickness



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

and now

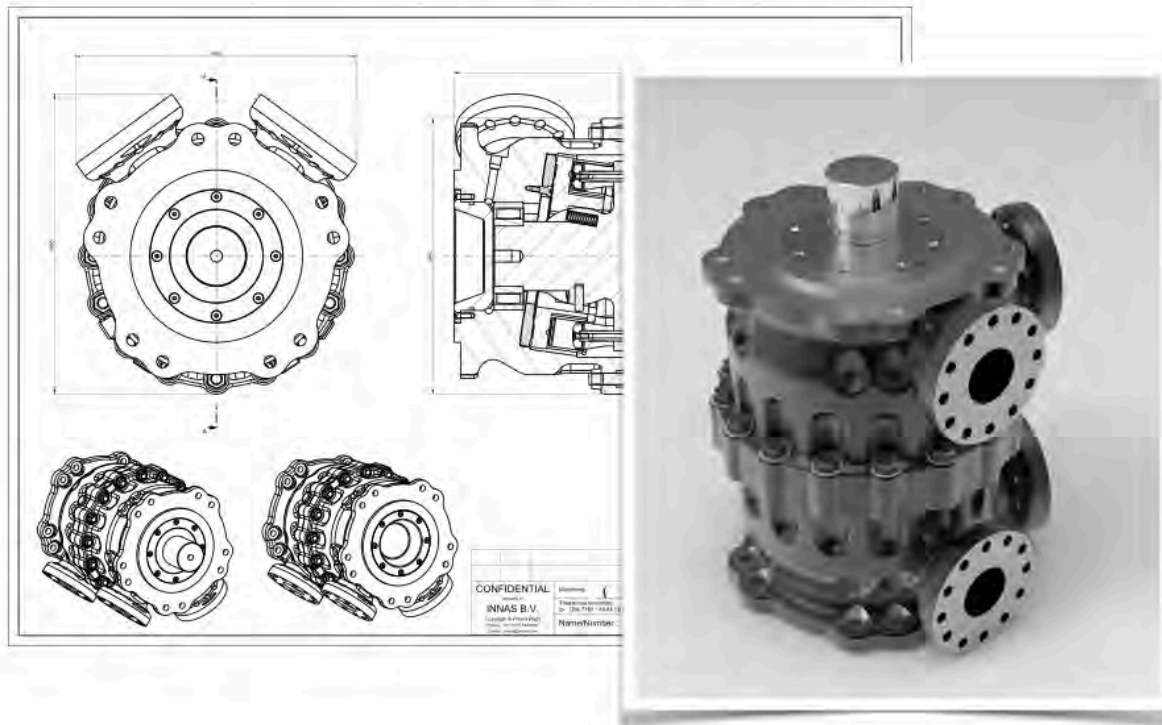


And now... there is this one question. Not just 'a question'. But the 64.000 dollar question:

Who is the company that will be producing these pumps and motors?

Who is our licensee?

# Hydrautrans



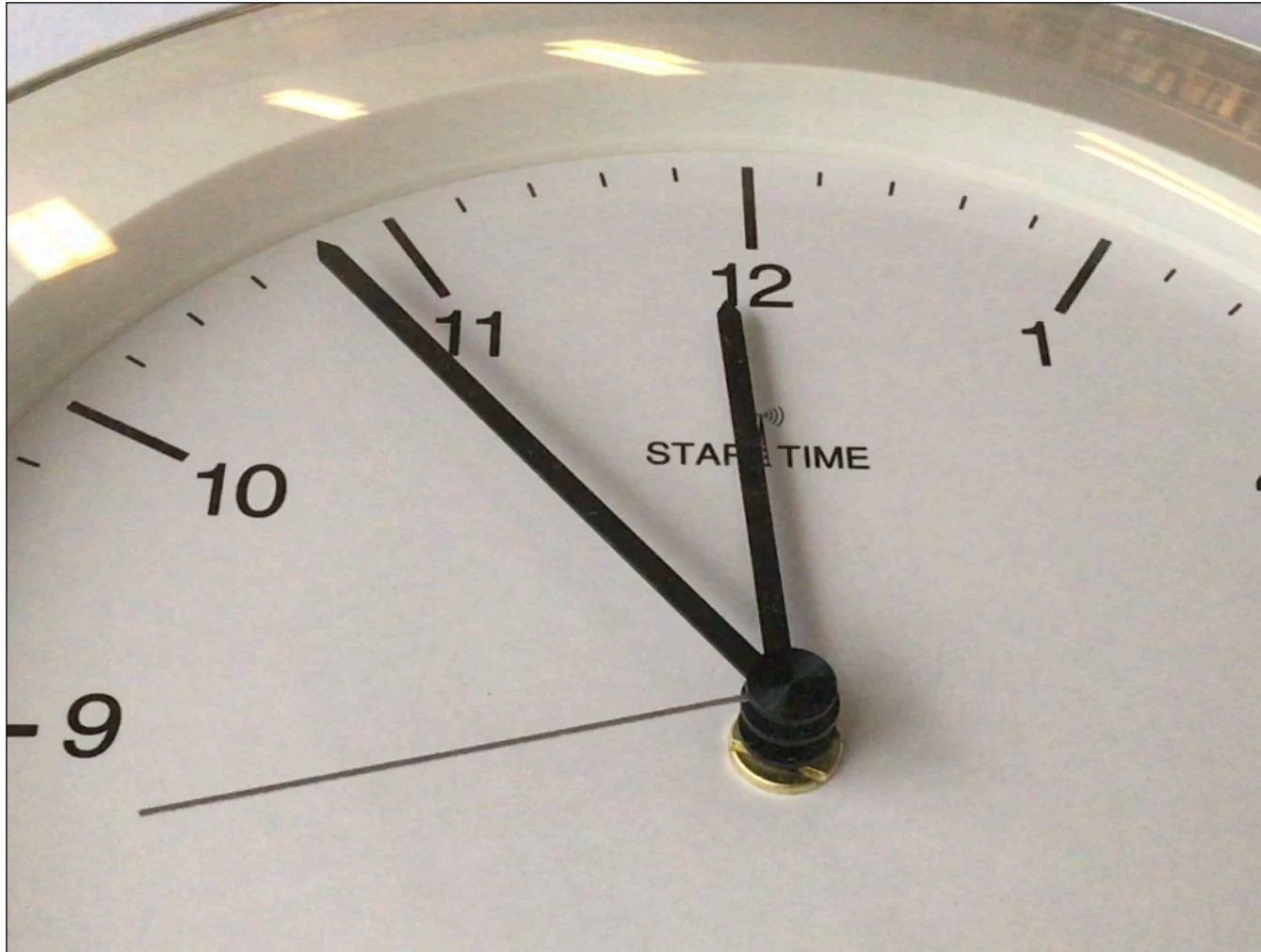
There is not a single answer to this question. You should know that we have more than one licensee.

The company Hydrautrans is one of them. This company is developing a new hydrostatic transmission for large, megasized wind turbines.

They have decided to use floating cup pumps and motors. The unit you are seeing here has a displacement of 5 liters per revolution and a power of 3.5 megawatt.

But I guess, that was not the answer you are waiting for.





I'm afraid I will have to disappoint you. I can't tell you who our other industrial contacts are. But I can tell you that I have great confidence in our partners. I deeply admire the courage and the skills of our licensees.

But that's all I can tell. You will have to wait another year before they will make a public announcement.

I know, a year is a long time to wait. On the other hand...



Time is just an illusion.

Thank you