AMERICAN CONSULTING ENGINEERS COUNCIL'S

HEAVY MOVABLE STRUCTURES MOVABLE BRIDGES AFFILIATE

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SESSION WORKSHOP NOTES

Sesssion (3-9)
"New Development in Hydraulic Cylinder Concept", Jacques Wels,
Hydraudyne Cylinders, Netherlands

New developments in cylinder design

In the past 5 years the development of hydraulic cylinder design has accelerated. For instance the working pressure is increasing to 250-320 bar (3600-4640 psi). Hydraulic cylinders are used in a wider variety of applications and environments. These higher demands on performance and quality asks for INNOVATION.

this challenge developed the revolutionary and unique CERAMAX 1000 rod coating.
the concept combines modern materials with optimized sealing and bearing systems. This results in the CERAMAX CYLINDER, which is regarded as the standard for the future.

Cylinders in Civil Engineering

During the 2nd Biennial Movable Bridge Symposium (November 1987) the fundamental engineering aspects of the hydraulic cylinder were introduced. In addition to this we present the most recent developments.

The basic design of a typical Civil cylinder can be divided in the following main items:

Bearings

Until now bronze was the common bearing material. Because of higher demands and safety requirements a Polyester based impregnated fabric called "ORKOT"
is more wear resistant and ductile than bronze. The mechanical properties of Orkot (table A) well exceed the properties of bronze. With Orkot a creative and simple solution can be found for surface pressure concentrations caused by high bending and side loads (fig. 1).

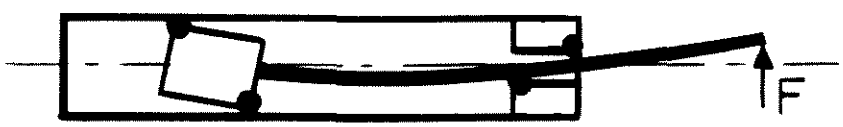

fig. 1.

The following example fig. 2a shows a bearing construction that proved to be not effective enough to accept heavy side loads because of deflection of the piston rod. The cylinder head and piston had to be modified with the same outline dimensions of the cylinder as before and at the same time able to take the side loads.

The bronze bearing bushes have been replaced by orkot to accept peak stresses at the bearing ends by ductility. The bearing length has also increased (fig. 2b).

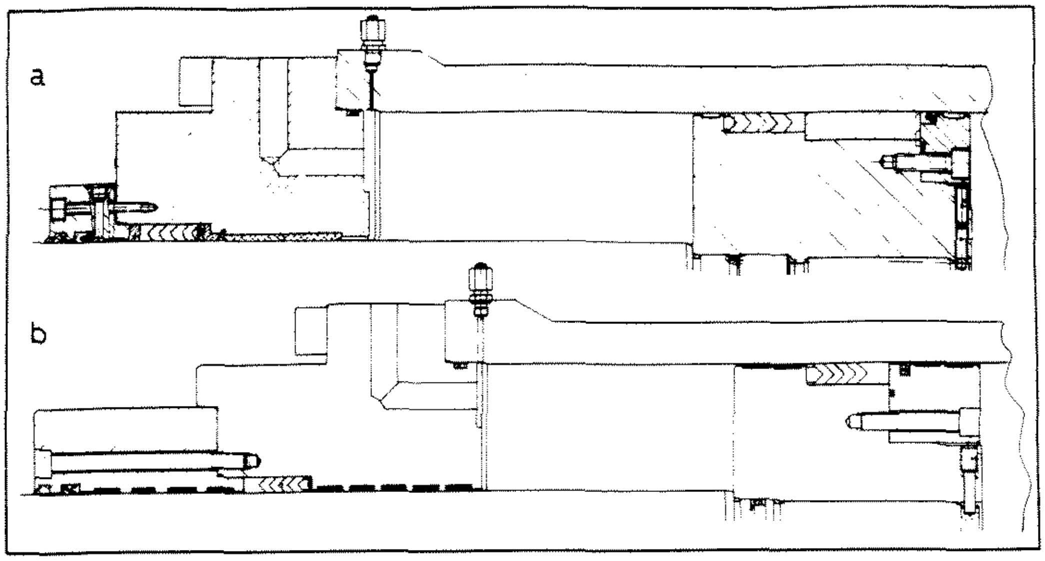

fig. 2a and 2b

Sealing system
Although leakage in all applications is unacceptable it has to be excluded because of environmental reasons. Pollution of the surface water can not be allowed. It is accepted worldwide that the chevron seal is the best solution. It offers heavy duty zero-leak sealing, but has a risk in running dry. This causes extensive wear and possibly stick-slip, noises and vibrations.
Combinations of new bearing materials and modern seals proved to be very effective.

The following sealing systems can be distinguished:
Fig. 3a shows the classic execution of a bearing and sealing combination on the head side.
Fig. 3b uses the same chevron seals, however now in combination with the Orkot bearing rings. This execution can take 3 to 4 times more side loads within the same bearing length as fig 3a.
Fig. 3c shows a modern advanced sealing system using Orkot and compact seals in tandem execution in combination with a double acting wiper. This also offers a zero-leak design. The compact sealing system has low friction properties and avoids stick-slip problems. Recent developments of the compact sealing compounds resulted in a material (zurcon) that is excellent wear resistant and has better sealing properties than Teflon.

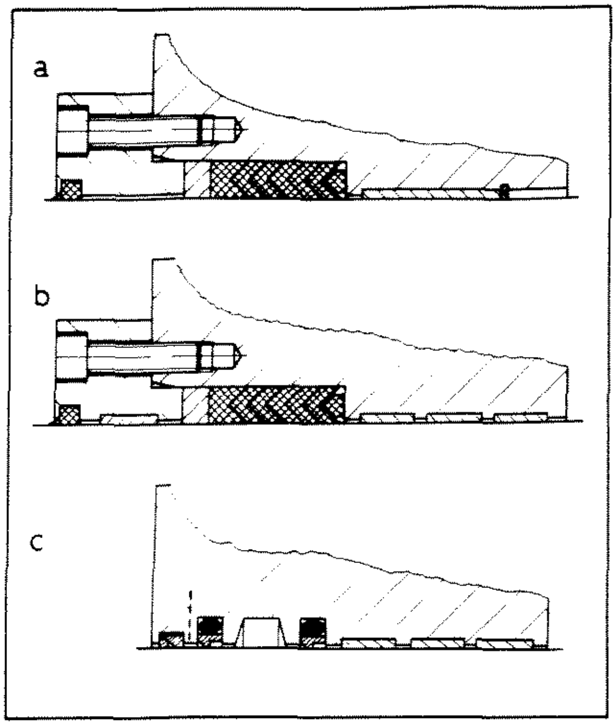

fig. 3a, 3b and 3c.

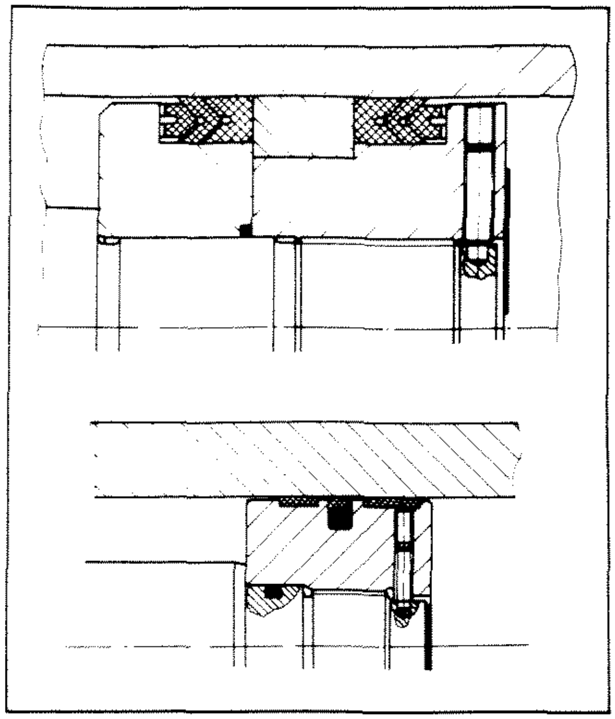

fig. 4.

Similar systems are used for pistons (fig. 4). A compact seal on the piston also offers the advantage of a one piece piston design.

Cast iron piston rings are totally outdated. By design, cast iron rings do not offer a zero leak sealing. Side loads on the cylinder can cause the piston rings to score the inside of the cylinder tube over a periode of time. This internal wear when combined with contamination of the hydraulic fluid will cause internal leakage across the piston and premature cylinder failure.

<u>Wiper</u>
Every cylinder is provided with a wiper to keep out all dirt and dust. Conventional designs were using rubber wipers.
A new development is the use of a hard polyester wiper which is tough and abrasion resistant.
Besides a heavy duty wiper function it also has an ice scraping function.
Bronze ice scrapers which are normally used have a high risk of scratching the rod. Dirt that comes behind the bronze scraper will collect between the scraper and causes rod damage.

Cylinder shell

The most widely applied shell material is St. 52.3N, which is a hot rolled seamless normalized tube. The use of cold drawn tube has to be avoided, because after welding and/or machining internal stresses will influence straightness, concentricity and roundness of the bore. By using high strength fine grain materials the outside diameter can be reduced within the same safety factor. Higher demands and requirements can be met more easy without a extreme increase in wall thickness. For cylinders working under an angle, an extreme wall thickness will have a negative influence on the deflection of the piston rod, the buckling situation and the bending stresses.

Example:

bore	500 mm	(20")
pressure	345 bar	(5000 psi)
shell length	2540 mm	(100")

Calculation based on ASME BPVC

	yield	nett OD	Wall thickness	Weight
St 52.3N	300 N/mm2	667 mm	84 mm	3002 kg
	(43500 psi)	(26.3")	(3.3")	(6604 lbs)
MW 450V	450 N/mm2	643 mm	72 mm	2518 kg
	(65250 psi)	(25.3")	(2.8")	(5540 lbs)

weight reduction 484 kg (1064 lbs)

Materials

For a list of main materials used in a hydraulic cylinder based on DIN standard, see table B.

Head and bottom

For maintenance purposes a bolted head and bottom is required. The diameter of the static seal in the head and bottom is slightly greater than the bore, so maintenance (re-honing) can be done without replacing the head and bottom. Only the piston has to be made to the actual inside diameter of the bore.

Piston rod and Ceramax piston rod coating

Hydraulic cylinders, in particular piston rods, in many applications are exposed to extremely aggressive environmental conditions. These include corrosion and mechanical damage such as scratching and wear.

Following intensive research to find the most appropriate composition of ceramic raw materials, combined with the development and control a specific manufacturing process is now able to produce an unique piston rod protection known as CERAMAX.

Years of trials, including field applications, confirm that Ceramax has a number of unique properties, in particular remarkable resistance to corrosion and abrasion.

This Ceramax is very different from conventional piston-rod protective finishes, and guarantees an exceptionally long life.
standard and special cylinders are available with Ceramax protection.

The black-coloured protective ceramic layer on the piston-rods of Ceramax cylinders is homogenous, a non-conductor, and impermeable. The layer is hard, yet sufficiently elastic to flex with the cylinder-rod. The mechanical properties of the Ceramax, like impact resistance, bending strength and strength of bond to substrate will adequately resist shock and loading within the mechanical limits of the rod material.

To many accelerated salt-spray corrosion test, according to ASTM B 287, were carried out during the development period. Comparison tests between Ceramax, hard chromium plating, nickel chromium plating and hard chromium plated stainless steel were also conducted.
The Ceramax layer withstands at least 1000 hours of salt spray according to DIN 50021 ESS (fig. 5).

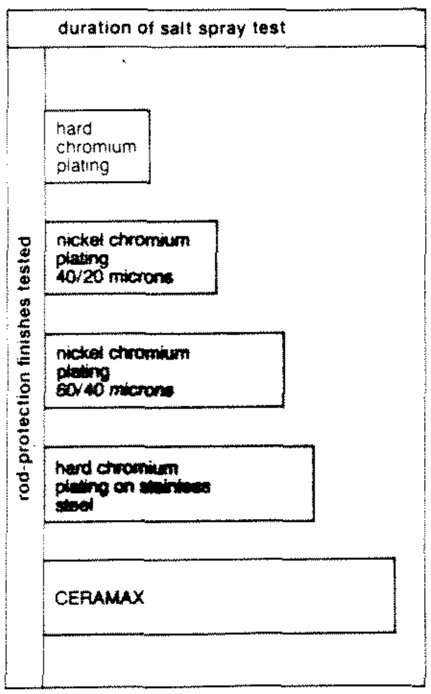

fig. 5.

In addition to this, together with this development, a new complete cylinder type was born, the Ceramax-cylinder. This cylinder concept combines all new developments such as discussed before, and for that "The standard for the future".

HYF 10003/2

Thanks to the Ceramax development, we have succeeded to introduce a new position indicator, which can be used in a standard design and has a high accuracy independent from the stroke.
The electronic construction is so, that it can be build-in in all existing systems.

This system in combination with a valve manifold block direct mounted on the cylinder, creates a so called "INTELLIGENT CYLINDER".

Boxtel
Oktober 1990
J.A.C. Wels

TABLE A

COMPARISON BRONZE/IMPREGNATED FABRIC (ORKOT) BEARING MATERIALS

		Bronze RG7	Orkot TLG
Compressive strength static	N/mm2 (psi)	90 (13000)	345 (50000)
Surface pressure dynamic	N/mm2 (psi)	5 (725)	15-20 (2175-2900)
Shock loads dynamic	N/mm2 (psi)	30 (4350)	115 (16700)
Friction dynamic oil lubricated		0.05	0.02
Contact angle	degrees	80	120
Wear resistance		fair	very good
Electrical conductor		yes	no
Bearing execution		bushing welded- overlay	split ring

TABLE B

MAIN MATERIALS FOR HYDRAULIC CYLINDERS

	DIN	WSTNR	ASTM*	
Cylindershell				
St 52.3N	17121	1.0570	A252	Gr. 3
Mannesmann MW 450V, 20MnV6		1.5217	A542	Cl. 3
Piston rod				
St 52.3N	17100	1.0570	A572	Gr. 50
C45	17200	1.1191	A519	1045
25CrMo4V	17200	1.7218	A322	4130
34CrNiMo6V	17200	1.6582	A322	4340
42CrMo4V	17200	1.7225	A322	4140
X22CrNi17V	17440	1.4057	A276	431
X5CrNiMo17.12.2	17440	1.4401	A276	316
X2CrNiMo17.13.2	17440	1.4404	A276	316L
Other parts				
St 52.3N	17100	1.0570	A572	Gr. 50

*The ASTM Standards are the closest US equivalent to the DIN standards.

REFERENCE LIST BRIDGES

Ruppel brug	Belgium	40.7067	Sep 86	136.132E
Stade	Germany	40.7263	Jul 86	138.045E
Berendrecht	Belgium	40.7190	Jul 87	137.173E
Gebersdorf	Germany	40.7575	Nov 88	138.844C
Stone Ferry Bridge	UK	40.8334	Jun 89	119.011A0
Nord Schleuse	Germany	40.8791	Nov 89	3.005.150A0
Zeebrugge	Belgium	40.8345	Mrt 90	3.001.828A0
Sevilla	Spain	40.8889	May 90	3.005.818A0
Niantic River Bridge	USA	40.8375	Jun 90	3.001.963A1
Jan Berghaus Bruecke	Germany	40.8753	Jul 90	3.005.125A0
Galata Bridge	Turkey	40.8989	Sep 90	3.006.845A0