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The A11 Bascule Bridge

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Brief Overview of the A11 Bascule Bridge

One of the highlights of the new A11 motorway in Belgium is the double movable bascule bridge over the Boudewijn Canal. It is also the first movable bridge on a highway in Belgium. This landmark bridge forms part of a long and new viaduct, which is one of the largest and most striking constructions of the A11. Measuring 15 meters high and 72 meters long it is one of the eye catchers of the A11 project. The 12 km long new highway provides for a better connection between the seaport of Bruges and the inland.

The bascule bridge is equipped with a counter weight in order to reduce the force needed to open or close the bridge. Only a small unbalance is active on the balancing of the bridge. This unbalance including the external forces like wind etc… needs to be compensated in order to open or close the bridge. This is realized by means of the hydraulic power packs. The counter weight is not concealed in a bridge cellar but moves above the water level because of the highway constructed 15 meters above the water level.

Both bridges are equipped with 2 cylinders with a piston diameter of 800 mm, a rod diameter of 340 mm and a stroke of 4700 mm. The coating of the rod is Ni-Cr in order to protect the rod against corrosion and to improve friction whilst retracting and extracting the cylinder.

The opening and closing time of the bridge is set at 90 sec, making this type of bridge the fastest in Belgium. In order to achieve this speed, 5 power packs of 200 Kw were installed. To control the speed of the cylinders, frequency drives were used. By varying the frequency of the drive, a varying flow is generated by the pumps. When closing the bridge, the braking energy of the bridge is fed into the drives and thus into the power grid, making the drive system more energy efficient. With the available open standard multi ethernet interface, a connection is established with the master controller of the bridge. With the 5 power packs and the frequency converters in combination with the integrated motion control in the drives, a smart cascade regulation is made possible. This allows to use the bridge under all circumstances with the appropriate speed. The integrated safety features make it possible to cover all kinds of safety risks.

Apart from the cylinders and the power packs, more than 2 km of pipework was installed in order to transfer the hydraulic power from the hydraulic room up to the actuators. All pipework is provided in stainless steel.

The bridges are operated approximately 3 to 5 times per day.

1. Introduction

The project has been given form by a DBFM project. The term DBFM stands for “design”, “built”, “finance” and “maintenance”. This means that different contractors get the initiative to present a concept solution to the government. Furthermore, the winning party remains responsible for the good operation of the equipment for the next 30 years. All maintenance activities and availability of the bridge are the responsibility of the contractor. Very often, in these kind of projects, there are several contractors involved to form a temporary association. The hydraulic equipment supplier was working as a sub-contractor of the electrical contractor.

2. Bridge

The type of bridge that was chosen for this project was a bascule bridge with counterweight. As mentioned earlier, the bascule bridge is equipped with a counter weight in order to reduce the needed force to open or close the bridge.

3. Cylinder

From the actuator side, a double rod cylinder was selected (800/340/340/4700). Two parallel mounted cylinders under the highway lift and lower the bridge. Since the availability of the bridge played a very important role, 1 cylinder had to be able to lift or lower the bridge at any time. The opening and closing time performed are very short for this kind of bridges. In 90 seconds a complete stroke had to be executed. This to reduce delay on the highway as much as possible. The calculated force for which the cylinders need to compensate is mainly wind force. Calculated from the fixing points of the cylinder on the bridges, a total of maximum 7600kN has to be delivered per cylinder. This includes as well a one cylinder operation at reduced speed. This force corresponds with a system pressure of 190 bar. The dimensioning of the cylinder was a combination of maximum allowed pressure and the calculation method (buckling) using the technical specification SB270.

Regarding the coating of the cylinder rod, a nickel-Chrome (60/50) coating was chosen. This coating is described in the SB270 specification along with ceramic coating. These days, other coatings like metallic coating are getting more and more in the market (thermally sprayed or laser cladding) see environment constraints.

The cylinders were mounted in a gimbal suspension by means of trunnions welded on the cylinder tube. The end of the rod of the cylinder was provided with a thread in order to screw on the eye (fixing point to the bridge). The eye and gimbal (included the bearings) were provided by the mechanical company.


4. Hydraulic Concept

The question how to control the whole system brought us to the question which type of hydraulic concept we'd chose. In general, we work in a closed loop system where the pump controls the speed of the cylinders. The advantage you get by choosing a closed loop system is that it's a very robust system where the hydraulics is always driven by the electric grid and external elements mainly change in temperatures (winter, summer) hardly influence the good functioning of the system. This in contradiction to open loop systems where speed is controlled by throttling oil column (proportional). The closed loop hydraulic circuit in combination with a double rod cylinder made the lay out of the hydraulic circuit very simple. Because no compensation of oil volumes has to be considered, a small boost pump will do the job for refreshing the oil of the system.

The advantages of the closed loop system with the double rod cylinder are:

- Robust system and very reliable
- The load is always driven by means of the pump / E-motor => less heat dissipation
- Less oil exchange with the air since the oil level remains constant => less contamination
- Easy control
- Counter rod gives extra stability to the cylinder (bearing)

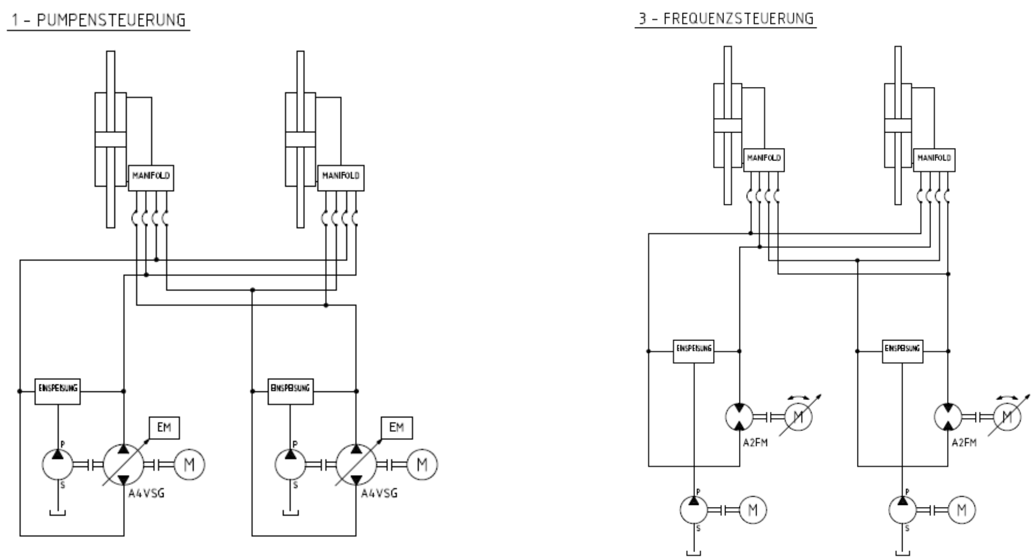
A disadvantage is the cost factor since a counter rod has to be fabricated.

5. Motor Pump Unit

From the pump-motor side, we chose a variable frequency motor/drive to control the speed of the pump. By changing the frequency of the E-motor, a variable flow was generated by the main pump. The pump is actually a hydraulic motor since it has to deliver pressure on both sides of the cylinder depending how the bridge is operated in combination with the external forces like wind etc. Rotating the E-motor clockwise will open the bridge, rotating the E-motor counter clockwise will close the bridge. The pump is a 500 cc bent axis motor. This motor is an axial piston motor with a fixed displacement. The motor has an axial tapered piston rotary group of bent-axis design for hydrostatic drives in open and closed loops. One important aspect to consider is the selection motor pump of the drive. When using frequency controlled drives, you're controlling the torque of the E-motor. In turn, this torque depends on the displacement of the pump and the pressure of the system. Electrical and hydraulic engineers need to discuss this issue since the drive needs to provide sufficient torque/current. Sometimes it might by more interesting to choose a 1000 rpm motor instead of a 1500 rpm motor to optimize the pump-motor-drive combination.

An alternative in this case could have been, instead of changing the speed of the E-motor, to change the swivel angle of a variable piston pump. In this case an axial piston pump with an electro mechanic control of the swashplate could have done the job as well.

Principle



The Question is of course which one to use. From the electric point of view, it makes sense to change the speed of the E-motor to control the pump flow. From the hydraulic point of view it makes sense to control the flow by means of a constant speed E-motor in combination with variable pump. From the service point of view, for both the solutions pros and cons can be stated.

A very important aspect with a frequency controlled application is a suitable selection of the drive. Since torque (current) is the leading condition, this sometimes leads to over dimensioning and in the end leads to a more expensive solution. Using an EM control on the pump gives more freedom to optimize the installation (optimized inclination angle of the swash plate). When using drives, the drive is designed to reach the peak torque/force which in reality might never occur. A standard E-motor running at 1500 rpm and reaching overload conditions for a brief period of time, hardly senses these extreme conditions. On the other hand when using a pump control, the hydraulic pump is foreseen with a control system that needs correct piloting versus a more straight forward constant pump running at a variable speed. In the case of the A11, we agreed to go for the solution with the frequency controlled E-motors. The E-motor, is equipped with an electro-mechanic brake. Before the drive actuates the motor, the brake has to be released. The use of the brake is a redundant safety in the hydraulic circuit. In case the hydraulic system should fail to stop the bridge, the disc brake built on to the E-motor will stop the movement of the bridge. Conclusion: in case of failure of the electric grid, you always have a safe stop of the bridge. The E-motor is also equipped with a constant cooling fan.

6. Drives

The drives to operate the E-motors were as well part of our scope of delivery. We implemented for this application the water cooled drives. These drives control the movement of the E-motor and give the feedback to the master controller (safety PLC) of the customer. When receiving the starting signal from the master PLC, the drives ramp up the speed of the E-motor and return the signal to the master controller “at speed”. The drives in this concept are operating mainly as speed controllers. The cooling of the drives is executed by a redundant water cooling circuit. The braking energy of the drives when lowering the bridge is fed back into the electric grid.

Form the power side, we calculated 5 times 200 Kw E-motors (per bridge). This power serves to open and close the bridge within 90 sec. but also guarantees an extra safety regarding the availability of the bridge. Even with 4 motor-pump sets the movement of the bridge can be achieved within 90 sec. In worst case, even with 1 motor pump set, the bridge can be operated.

7. Pipework

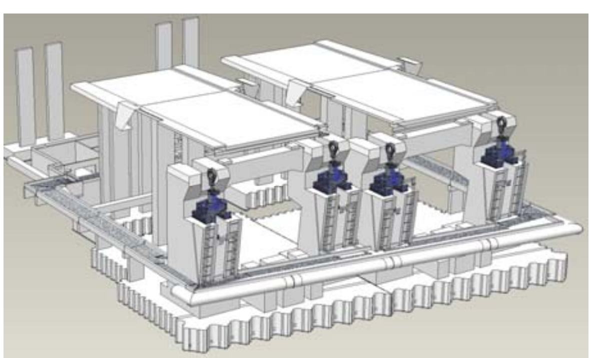
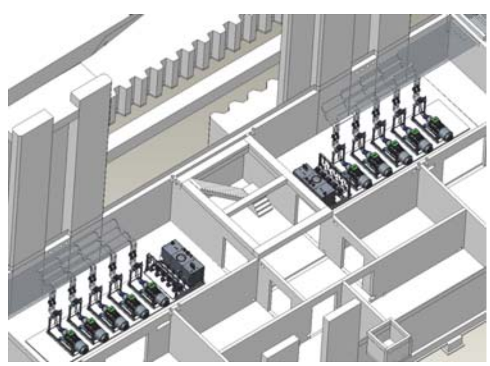
To transport the hydraulic energy towards the actuators, stainless steel pipework was mounted. From each motor pump set a separate pipework was installed up to the manifold of the cylinder. 2 Reasons:

- The oil speed in pressure lines had to be below 3 m/s. The sizing of the pipework had to be calculated according to this guideline. Installing collectors would have resulted in pipe sizes out of "standard". The main pressure lines in 60,3 X 6 mm stainless steel 316L
- Separate pipework up to the manifold has provided the advantage that in case of failure in one pipeline, doesn't compromise the continuation of the bridge movement.


8. FAT, Installation and Commissioning

The completion of the hydraulic equipment was done in different stages. Before releasing the production, an intensive engineering phase was executed. A summary of the different engineering phases were:

- Delivering all the calculation notes for the hydraulic system and cylinders (bascule cylinders and buffer cylinders)
- Designing all the sub-assemblies of the installation
- Implementing all models (mechanic, hydraulic, steel) into a BIM model

After releasing all the parts for production, the assembly of the sub-assemblies was started including the FAT of each part. For testing the motor pump sets, the drive was connected to one motor pump set in order to set the correct parameters on the pump. The FAT of the cylinders took place in the cylinder factory in Boxtel where the standard SB270 FAT tests were executed. These test implied a pressure (test pressure for x time) and a running dry test.

After the positive acceptance test, the cylinders were transported to the mechanic supplier who mounted the cylinders into the gimbal. Afterwards, the hydraulic manifolds and piping were mounted on the cylinder. The installation of the cylinder on the bridge supports was done by means of a floating carrier with built on crane.

After this operation was done, the bridge was ready to be installed. Also this operation was done with a floating carrier and took 1 day per bridge (including filling the counter weight). After installation of the bridges, the coupling of the hydraulic cylinders with the bridge took place.

Before operating the hydraulic cylinders, the complete system was filled with hydraulic oil and de-aired. The type of oil, we selected was bio oil VG22. The reason for using this type of oil is mainly because of environmental issues. We didn't have a bridge cellar and in case of hydraulic leakage, oil could be spilled into the canal. Using bio oil reduced the risk of severe contamination of the canal in case of extreme oil spillage.

The reservoir of the hydraulic system contains 2500 liter of oil. Since the hydraulic concept was chosen by means of a closed circuit in combination with a double rod cylinder, hardly any oil exchange is noticeable (zero in theory). This results in a stable oil level and reduced contamination of the oil (air inlet practically zero). The filtration of the system is performed by a separate off line conditioning unit and by the boost/flushing pumps (1 per main motor pump unit).

The final step was the commissioning and test phase of the bridge. In this phase, all the different features of the bridge movement were tested (nominal speed, reduced motor operation, emergency stops, cable break)

After the test period, the A11 highway was officially opened. Since then, all traffic coming and going to the harbor of Zeebrugge is taking the A11 highway. Since the opening in 2017, every day more than 10.000 trucks and cars are driving over the A11 highway.

In the meantime, all partners remain responsible for the good functioning of the bridge. Every quarter, an inspection is done to the hydraulic, electric and mechanic components. Once a year, a thorough maintenance is executed (changing the filter elements, oil samples, etc.)

Conclusion

The success of installing the A11 bridge was a combination of good team work within the company and with all the involved partners. A good communication and central coordination was crucial in this project. The chosen drive concept was the biggest variable speed application so far made for bascule bridges on the Belgian market. This concept has so far proven that reliability is one of the key elements in this kind of applications.