VHT VAN HALTEREN TECHNOLOGIES

Stick-slip problems solved for the Oosterscheldekering

A solution was successfully proposed
in the form of a sealing system tailored to the application

Right from the start of the commissioning of the Oosterscheldekering (Estern Scheldt storm surge barrier) the stick-slip effect was noticed associated with the hydraulic cylinders which open and close the sluice gates. This has indeed been investigated, but until recently without satisfactory results. A solution was successfully proposed in the form of a sealing system tailored to the application. Rijkswaterstaat is now busy replacing all seals belonging to the 124 cylinders (originating from the third batch) of the 62 sluice gates.

The 9 km long Oosterscheldekering is the largest part of the delta works and functions as a closable storm surge barrier. This means that the 62 movable sluice gates are closed when the expected water level reaches or exceeds 3 m +NAP (The Netherlands National Datum). Closing – and opening again – of the sluice gates is done using large hydraulic cylinders, two cylinders per gate. This is a precise and demanding job as the gates all have a length of 42 m, a height of between 6 and 12 m and an associated weight varying from 260 – 480 tonnes.

Stick-slip

Although the gates have by now been successfully used some 26 times, besides being regularly opened and closed for testing purposes, up till now this has never worked smoothly enough, hindered by the stick-slip effect when closing and opening the sluice gates ever since the commissioning of the

Oosterscheldekering. First and foremost this means that any movements are accompanied by a relatively large amount of noise and vibrations causing the sealing to wear faster and start to leak. Attention has been paid to it over the years and various investigations have been carried out by different external parties, but up till now without any satisfactory results. It was clear that the sealing system was at fault, but where exactly the actual problem was a lot more difficult to ascertain.

VHT has done a lot of research over the last few decades in the tribology field. Tribology investigates the dynamic behavior of contact surfaces of all sorts of materials under various conditions. As a consequence a large number of different parameters play a part here: the characteristics of the different surfaces (material, surface structure etc.), but also the prevailing conditions and the lubrication used (in this case oil) which is present between the surfaces. Due to the complex combination of a large number of factors it's tricky to predict the behavior of the surfaces. Experience teaches that approaching problems in the tribology field from a purely theoretical viewpoint does not lead to the desired solution; this was also the case with the Oosterscheldekering. In order to draw the correct conclusions a certain amount of experience and intuition is necessary. The Oosterscheldekering has seals which are continuously loaded under pressure; the sluice gates after all just hang in the oil column and are only sporadically moved. Every two weeks we did a test movement in which the gates moved 1.5 m and four times a year the gates are fully closed. The rest of the time they are not moving but the sealing is under continuous hydraulic pressure.

Project-based approach

Thanks to the experience and knowledge of VHT, it was not very difficult to determine the cause of the problem and to select a possible solution. It was a lot more difficult to prove beforehand that the proposed solution would work. And that was very important due to the fact that this meant an alteration of 124 cylinders (two per sluice gate). So a project-based approach was chosen, consisting of eight sub-projects for which it was agreed between Rijkswaterstaat and VHT that after each stage there would be consultation on the desire / necessity of proceeding to the next phase. The sub-projects were as follows:

1. Start-up of the project including theoretical assessment of the situation
2. Investigation into the cause of the stick-slip effect in two cylinders
3. Advice on the application of the stick-slip-free solution.
4. Delivery of this solution for two cylinders
5. Support for the subcontractor on the implementation of the solution
6. Investigation of the original seals which were removed
7. On-site investigation and testing of the solution
8. Final report / project closure

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Theoretical investigation

The drawings and the various reports which had been made up in the past, combined with the measurements carried out and the knowledge and experience which VHT brought along with them, led to the conclusion that the problem was in the sealing system. This conclusion was also drawn on the basis of eliminating other possible causes such as the sluice gate guides (this produced a little stick-slip, but not enough to explain the problems) and the surface structure of the rod. Besides this a number of simulations were carried out to substantiate the (then) suspected cause of the stick-slip and to obtain detailed information.

The original main sealing system consists of a combination of different seals, starting with a pressure ring, followed by a few V-rings and culminating in a support ring on the pressure side. The V-rings were stuck and partly worn due to lack of lubrication. The cause of lack of lubrication was due to the fact that the support ring acted as sealer. It was made of a soft compound which caused relatively high amounts of static and dynamic friction thereby preventing lubrication. The effect was clearly visible in the measurements which showed a typical saw tooth combined with other stick-slip effects. It was also clear that after the pressure was released (when the sluice gate was on the threshold) the stick-slip effects were reduced. After relieving the pressure, the lubrication (hydraulic oil) could penetrate past the support ring to the sealing V-rings.

Advised solution

A number of possible sealing systems were then tested at laboratory scale in order to demonstrate their suitability. The choice eventually fell on a VHT (partly in-house) designed rubber canvas seal with a roof-shaped sealing. This choice was not only based on the removal of the stick-slip problems, but also on other (logical) requirements which were laid down by Rijkswaterstaat. For instance the solution had to be free of leakage, divisible, have an expected life span of more than 40 years with a movement of 8 km (this meant that the aging of the materials had to be studied too) and must of course fit in the existing room and be suitable for the current configuration of the barrier in the current situation (salt water, outside application, cylinders which are mostly extended). All factors were taken into account and so VHT looked at the materials of the cylinder and the sealing, the geometry of the sealing as well as the applied lubricant. Among other things, this could be done at short notice because VHT has experience with all known rod coatings – including their specific surface structures – in combination with known sealing systems.

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The sealing was then constructed for three cylinders. Exchanging the sealing is an expert job in itself. Workers have to handle large cylinders which cannot simply be removed from the structure but parts of which must be dismantled in order to apply the sealing. The assembly of the new sealing is a very delicate job. So it had to be accurately determined how the exchange could be done best with regard to efficiency and safety. This part of the VHT advice was also an essential ingredient in the total product.

Replacement proces

After completing the project and writing a 278-page report, a bigger test phase was started by fitting another 20 cylinders (for ten sluice gates) with new sealing and then to monitor them for the period of a year. When these results were in order, Rijkswaterstaat decided to fit the rest of the cylinders with new sealing systems. The job has now been put to tender at an external party from Friesland in accordance with European procurement regulations. VHT supplied all support possible to train the employees of that company and to inform them on the correct assembly of the sealing. Also the necessary steps were taken with regard to logistics to enable the assembly to be done as smoothly as possible. The manufacturer of the sealing was for instance advised concerning the packaging of the seals and the packaging material to be used. On the basis of this, watertight wooden boxes were opted for – after all, the boxes are stored outside during the replacement of the sealing – the various components being packaged so that they could be removed in the right order for assembly. Furthermore, the first series was checked for 100% by VHT for completeness, possible damage and the packaging method. On the basis of this the manufacturer of the sealing adjusted their procedures so as to minimize the chance of error.

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