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Helicopter Noise Control Ekofisk Field – Full Scale Mockup Tests

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1 Introduction

The platform known as Ekofisk 2/4L (EKOL) is under construction in Singapore. It will be delivered to its owner, ConocoPhillips, in 2013. Multiconsult is engaged in the acoustical design of the platform by SMOE, the contracting ship yard. This paper summarizes the efforts at controlling helicopter noise, specifically the full scale mockup tests performed in Singapore in January 2011. Other aspects of the platform design may be presented at a later point in time.

2 Issues

The EKOL platform includes a helideck with two hangars, located on top of one end of the accommodation modules. The platform is the centre of the helicopter operations for ConocoPhillips' operations in this part of the North Sea. The helideck serves traffic both to shore, typically accomplished with larger Sikorsky S-92 aircraft, and inter-platform traffic, mostly done with the somewhat smaller Super Puma helicopters from Aerospatiale.

The EKOL platform can be the centre of more than 50 helicopter operations per day, making it one of the busiest airports in Norway. Thus, there is a challenge in combining this with its being a hotel for 552 workers, some of whom also sleep during the daytime.

The platform is being designed to be placed on its jacket in two lifts. The main lift will comprise the platform itself, while the second lift will include the generator module. This places a severe weight restriction on the platform. The acoustical design team has thus had to consider optimizing the noise reduction with respect to weight.

In addition, ConocoPhillips identified a further goal, for the helicopter noise not only to meet the normal NORSOK S-002 55 dBA limit, but in addition not to exceed 50 dBA, and, if possible, 45 dBA, in most of the cabins. An effort has been made to quantify the number of cabins exposed to these various classes of noise, for different facade designs.

3 Regulations and Measurement Options

Helicopter noise within the cabins is regulated by NORSOK S-002, [1], which states that a level of 55 dBA shall not be exceeded during helicopter operations. This rather imprecise statement was redefined for practical purposes to mean either SPL measured with "Slow" meter response or one-second L_{eq}.

The second of these metrics is well suited to modern noise measurement instrumentation. An overall integration period of, e.g., five minutes, can be established for the entire helicopter noise event, and this period subdivided into one-second subperiods, for each of which all the normal parameters, including noise spectra, are measured. Then, the identification of the highest sound level can easily be obtained by post-processing, where the average spectra for the highest events can also be derived.

3.1 Outdoor Helicopter Noise Spectrum

The standard measurement procedure for helicopter noise (see, e.g., [2]) includes a series of standard operations: take-off, landing and fly-by. The landing operation procedure includes a direct flyover at a prescribed height, whereas the fly-by measurement is made at a certain side distance. The helicopter is thus viewed from different angles for the different tests. This leads to quite different sound level spectra. The landing spectrum is then particularly influenced by the direct flyover and can include rather strong low frequency components.

A test for the S-92 helicopter was done by Avinor [3]. Particularly the landing noise shows prominent components in the 125 and 160 Hz third-octave bands. Using this landing noise spectrum made it practically impossible to predict even 55 dBA in cabins. Because measurements offshore had not corroborated very high cabin noise levels, and above all not this typical landing noise spectrum, a measurement program was designed to establish a typical offshore spectrum for helicopter operations. The measurements were made in July 2010 at the EKOH platform by Sinus AS and Multiconsult AS.

The measurements included a number of helicopter events. The one-second L_{eq} data were averaged for the ten time periods closest to the maximum A-weighted event. The highest low frequency events were found to be coincident with the highest A-weighted levels. The resulting spectra were plotted and averaged. The spectra were similar for both types of helicopters, and the differences between landing and take-off events also similar for both types. It was therefore decided that they would both be included in the average spectra. The helicopter events are not of uniform nature, being influenced by weather conditions and pilot behaviour, and the sample of helicopter events included was not sufficient to permit further refinement of data for each helicopter. For engineering purposes this was also not considered necessary.

The resulting spectra are shown in Figure 1, at a reference distance of about 40 meters.

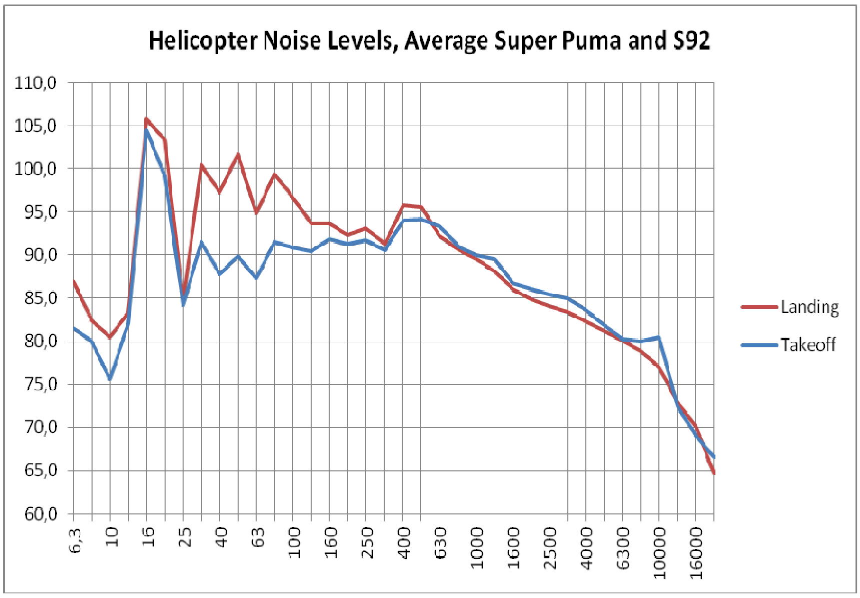

Figure 1: Practical Offshore Helicopter Noise Spectrum, 40 m Distance

The strong low frequency (blade passage) components can account for the feeling that one can have off shore, that one “feels” the helicopter approaching as much as one hears it. This component does not affect the A-weighted levels and is not considered strong enough to cause infrasound problems indoors.

The Avinor report landing noise spectrum showed values 10-12 dB higher at 125 and 160 Hz. This new, more “forgiving” spectrum (Figure 1) made it possible to predict lower values and to remove some of the nervousness about this issue that had previously infected the design team.

4 Noise Reduction Efforts

Early noise calculation was based on the use of steel plating thicker than the project standard six millimetres. A thickness of up to 18 mm was included, though this was later considered thicker than could practically be implemented.

Also, it is clear that the performance of the wall at low frequencies is stiffness controlled, rather than mass controlled. An additional effort was then started where other methods were to be investigated. A cooperation with Q-Ring was initiated. Q-Ring were to perform FEM-based analyses to evaluate alternative methods, particularly to avoid resonances in structural elements in the critical frequencies, but also to look for possibilities for stiffening the exterior wall structure. A number of ideas were tried out. The reporting of this work is left to Claes Fredö of Q-Ring.

Another element of work that was coordinated by Q-Ring was to investigate the possible use of active noise cancellation (ANC). This work proved that it is indeed possible to use active noise cancellation for low frequency helicopter sound. Up to 10 dB reduction was noted at 50 Hz. However, the technology was not ripe for commercial application, and further development of the method was necessary. In particular, the algorithm of the system needed modification, and the reaction speed would have to be improved by using feed-forward methods, i.e., picking up correlated ("prediction") signals outdoors. The design effort was also proceeding at a sufficient pace that it was not feasible to plan of – eventual -- electrical layouts for the ANC system, at the same time as the system had to be conceptualized. This would have required extraordinary sales skills in a complicated design team process! Still, the work showed that there is potential for this application, at least in a small, pre-defined area.

5 Mock-Up Testing

5.1 Mockup Rig Description

A full scale mock-up test rig was constructed at the SMOE yard in Singapore. The mock-up structure consisted of three cabins, a corridor and a utility area that contained control systems for the various technical functions of the mockup. Thus we could test two types of cabin walls and three different facade constructions, as well as different floor coverings and PA speaker solutions.

Pre-qualification of the mock-up structure showed problems in measuring the performance of the exterior walls. Above all, the flanking noise was a large problem. This was solved to an acceptable degree by constructing a large "room" outside the entire mockup structure, on the side where the test walls were located, including plywood walls and a steel floor. The entire mockup structure was elevated by about 1.5 m on a steel structure and located within a workshop building where other activities, some of them very noisy, were taking place. Most of the tests had to take place during periods with little noise in the workshop.

The tests were made using a standard acoustical measurement system, based on equipment of the Norsonic brand. The half dome loudspeaker system turned out to generate inadequate low frequency sound; this was not very surprising, given the effort at isolating just this noise! Therefore, as separate amplifier and loudspeaker intended for rock music purposes were added. This helped provide sufficient signal-to-noise ratios during testing.

Three outdoor wall structures were tested:

Table 1, Mockup Test Walls

Cabin	Bulkhead	Lining	Ceiling	Window
A	6 mm	35 mm STX	30 mm STX	Norac flat
B	6 mm w/RHS and ring stiffeners	Norac 50 mm	50 mm Norac	Norac bay
C	6 mm w/RHS and ring stiffeners	Norac 70 mm	50 mm Norac	TeamTec bay

The RHS (Rectangular Hollow Steel) profiles were used to stiffen the walls, in addition to ring stiffeners. After the initial testing and Q-Ring input this was considered one of the more practical options for stiffening the wall. It is a relatively heavy wall, since the stiffeners are heavy. A 12 mm wall panels with normal stiffening was tried out in an initial mockup test rig, but flanking noise problems prevented fully conclusive results.

5.2 Test results

Figure 2 shows the sound reduction test results for the three different wall constructions. In addition to the three full scale mockup tests, it also shows the results for the initial "mini-mockup" tests, which were influenced by flanking transmission.

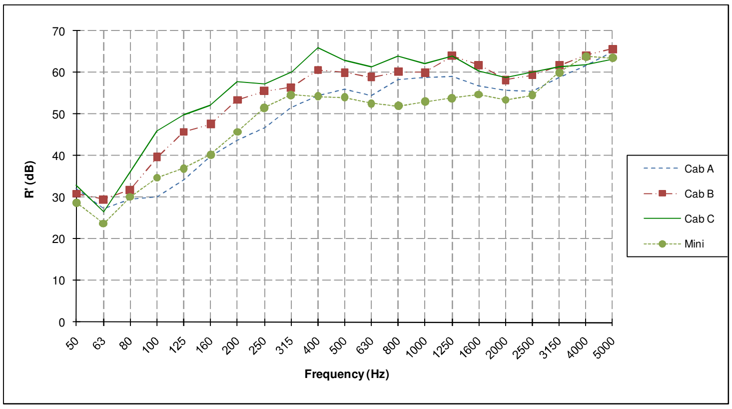

Figure 2, Mockup Exterior Wall Test Results

Figure 2 shows that there were significant differences between the various exterior walls. The biggest design difference between cabins B and C is probably the windows. The TeamTec window had an interior sash which was structurally isolated from the exterior wall, whereas the Norac windows included a stiff window box that connected the inner and the outer windows. This difference was translated also to other accommodation elements – primarily the exterior wall lining) that were in contact with the window box. The TeamTec window also included sound absorption between the inner and the outer sashes.

In addition to the standard noise reduction tests, extensive vibration measurements were performed on the cabin surfaces, using pink loudspeaker noise as excitation signal on the outside. This gave further information on the relative contributions of the various cabin surfaces.

None of the cabins had floating floors, as this is not foreseen for the project. The cabins are fitted with hard surface flooring. For frequencies above about 400-800Hz (highest for Cabin A, lowest for Cabin C) the floor vibrations were deciding for the total interior noise levels.

Helicopter noise levels were calculated in the most exposed cabins using the reference helicopter landing spectrum and the measured exterior wall construction reduction values. The results were 54 dBA for Cabin A, 48 dBA for Cabin B and 47 dBA for Cabin C. A further study determined the cabins where improved exterior walls were required. The Norac windows are project standard issue, and the differences at low frequencies (determining for A-weighted helicopter noise levels indoors) were not considered large enough that the otherwise more impressive TeamTec window should be used for the improved walls.

5.3 Other Findings of the Mockup Testing

The STX cabin modules include two separate linings between cabins, and the systems had no difficulty meeting the 45 dB R'_w requirement. A separate test program concluded that perforated ceilings were not required for noise control. Impact noise tests were made between cabins (not regulated), with very high resulting levels at high frequencies. Likewise, impact noise reduction between cabins at different elevations is not very good. However, with the relatively thick carpet chosen for the corridors, the impact insulation from corridor to cabin was excellent.

It appears that flanking was present in the mockup not only through the roof and floor of the mockup (in this case well controlled), but also sideways, from one cabin to the next. The less stiff and heavy Cabin A bulkhead generated vibrations also in the outer wall of Cabin B, which were not felt by the time one came to Cabin C. Cabins B and C should theoretically have showed similar values of wall vibrations, but this was not the case. This illustrated the diffculty in building a compact mockup for testing very different constructions.

Also, it was impossible to conduct a systematic test of the value of individual noise reduction measures, which would ideally have required moving different interior elements from cabin to cabin. This is not possible in a normal mockup situation, which is just as much designed to show fit and finish and can therefore not easily be taken apart and remounted.

The PA system testing may be described in future papers, but let it be said now that some loudspeakers showed the ability to cancel each other’s sound below 500 Hz! When turned on, the system came on with the phase such that cancellation occurred, and the phase had to be reversed manually. This may have implications for how loudspeakers should be mounted, relative to each other.

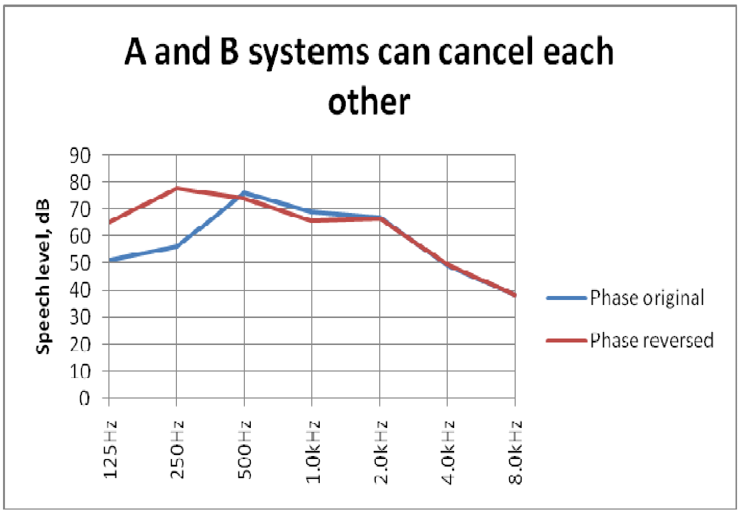

Figure 3, Cancellation Effects for PA Speakers, EKOL Mockup

References

[1] NOROSOK Standard S-002, Revision 4, August 2004

[2] US Federal Aviation Regulations Part 36

[3] OSLAS-AN-RA-0193, rev E02, date 02.11.2006 “Noise measurements on S-92”.