WTD 71 FWG

Wehrtechnische Dienststelle 71

Forschungsbereich
für Wasserschall und Geophysik

Cruise Report

r/v ELISABETH MANN BORGESE

Cruise-No. EMB 144

This report is based on preliminary data

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1. **Cruise No.:** EMB144

2. **Dates of the cruise:** from 17.11.2016 to 28.11.2016

3. **Particulars of the research vessel:**
   Name: ELISABETH MANN BORGESE (EMB)
   Nationality: Germany
   Operating Authority: WTD71

4. **Geographical area in which ship has operated:**
   Sognefjord, Norway

5. **Dates and names of ports of call**
   from Sunday, 20th, (first entering) to Thursday, 24th, (last leaving) of November 2016 daily entering and leaving of port of Høyanger, Norway.

6. **Purpose of the cruise**
   The purpose of the research cruise *NovEMBer2016 is* to improve the scientific understanding of flow noise generation and reduction from turbulent boundary layers in the near-field of mechanical structures. The research is embedded in a European project and is based on results obtained from the preceding sea trials *yellow*FLAME2013 (EMB056), *blazing*FLAME2014 (EMB084), and *cool*FLAME2015 (EMB112).

7. **Crew:**
   Name of master: Uwe Scholz
   Number of crew:

8. **Research staff:**
   Chief scientist: Dr. Jan Abshagen

   Scientists: Dr. Volkmar Nejedl, Dietmar Stiller

   Engineers: Jörg Schulz, Kai Haacks, Lars Prengel

   Technicians: Klaus Balzer

9. **Co-operating institutions:** FFI (NOR), Leonardo (ITA), INSEAN (ITA), CGS (NOR), Patria (FIN), FOI (SWE)

10. **Scientific equipment**

- Towed array for measurements of flow-induced noise at towing depth between 10 m and 30 m
- Freely drifting buoy with underwater sound transducer for sensor calibration and sound propagation measurements
- CTD aboard EMB for measurements of sound speed profiles

11 General remarks and preliminary results

11.1 Introduction

The research cruise *Nov*EMB*er*2016 (EMB144) was conducted with RV ELISABETH MANN BORGESE (EMB) in central Sognefjord, Norway in the period from 17th to 28th, October, 2016. In Figure 1 the measurement area south of Høyanger can be seen from RV ELISABETH MANN BORGESE during its entrance into the area on Sunday, 20th. The towing

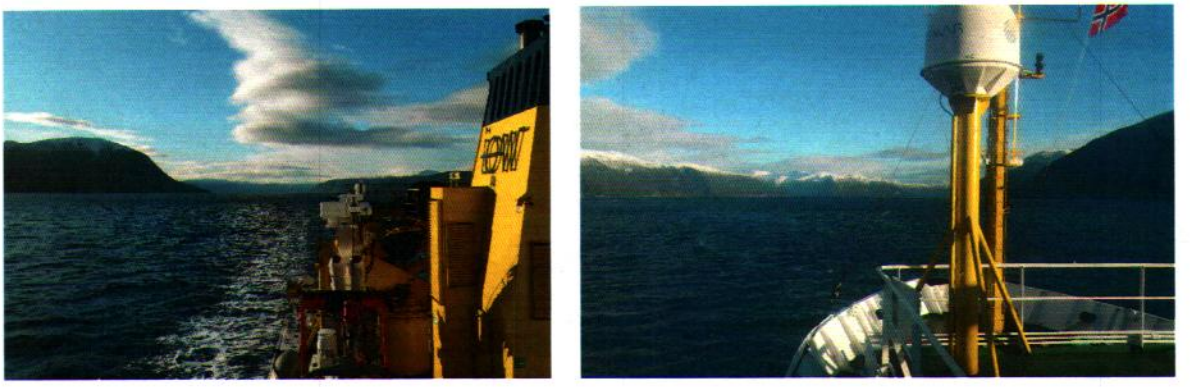

Figure 1: RV ELISABETH MANN BORGESE entering the measurement area in Sognefjord (south of Høyanger), Norway, on Sunday, 20th, November 2016.

experiment were conducted in the similar manner as in the previous research cruises *yellow*FLAME2013 [1], and *blazing*FLAME2014 [2], and *cool*FLAME2015 [3] which took place between 2013 and 2015. A description of the measurement procedure can be found in the cruise reports and in [4, 5]. During the research cruise *Nov*EMB*er*2016 several kinds of measurements have been performed. Instead of a towed body, the measurements were conducted with a line array that can either be operated as a towed or as a vertical array.

The general scientific aim of this research cruise was to improve the understanding of flow noise generation in towed arrays. The self noise experiments were accompanied by calibration measurements with a freely drifting projector buoy. The research cruise was embedded within an European project with partners from Norway, Sweden, Finland, Italy, and Germany. The results of the cruise will enter into a comparison with towed array systems from each partner.

11.2 Cruise and experiments

On Thursday, 17th, RV ELISABETH MANN BORGESE was loaded and equipped at WTD71 in Kiel (on the area of the former Naval Arsenal). It left Kiel at 7 p.m. and arrived in the

measurement area in central Sognefjord with some delay on Sunday, 20th, in the afternoon due to bad weather conditions during the transit. The journey of RV ELISABETH MANN BORGESE went through the Great Belt, the Kattegat, the Skagerrak, and the North Sea. Immediately after arrival in the measurement area tests of the measurement equipment were performed. During these tests the line array was launched as a vertical array. Furthermore, a sound speed profile was recorded with the CTD probe that is installed aboard RV ELISABETH MANN BORGESE.

(a) (b)

Figure 2: Pictures of measurement equipment: Winch with towed array aboard RV ELISABETH MANN BORGESE (a) and towed array before launching (b).

On Monday, 21st, and Tuesday, 22nd, towing experiments were performed with the line array in order to determine the flow noise induced in the interior of the antenna system and the dependence of the noise level on towing speed. The winch with the array system on the deck of RV ELISABETH MANN BORGESE (a) and the array just before launching (b) can be seen in Figure 2. The towing depth of the antenna was above 20m depth and the array was towed about 150m behind RV ELISABETH MANN BORGESE. In Figure 3 a power spectral density measured with the towed array at a speed of 6.4kn is depicted. In this case the ambient noise dominates the signal for frequencies above 200Hz while for lower frequencies the self noise becomes more relevant. Though on the second day of measurements the weather was very stormy, the experiments have been completed successfully. Due to the relatively high level of ambient noise a detailed data analysis with sophisticated methods from array signal processing is required [4].

Calibration of the array has been performed on Wednesday, 23rd, and on Thursday, 24th with two different methods. On Wednesday the array was towed behind RV ELISABETH MANN BORGESE and hydroacoustics signals were emitted from a freely drifting projector buoy. The drifting buoy was launched and recovered in Sognefjord before and after the towed array, respectively. Pictures of the buoy during operation can be seen in Figure 4. Two kind of signals, CW pulses and LFM sweeps, were used for calibration. The calibration

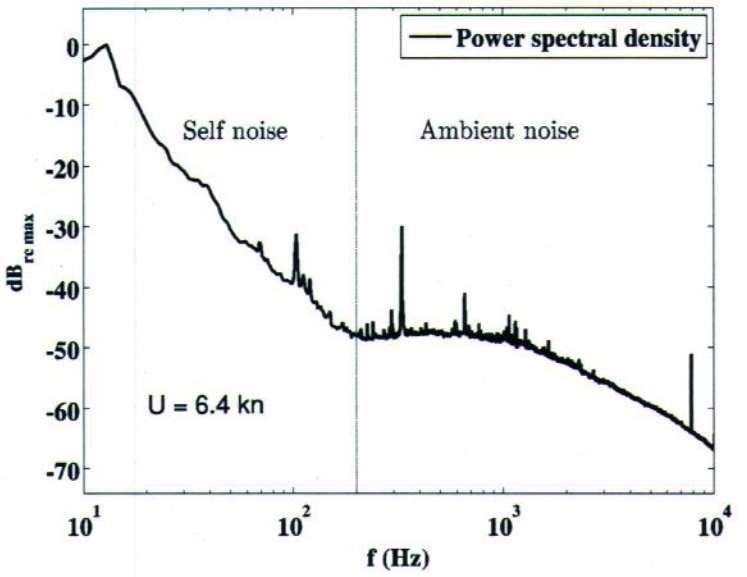

Figure 3: Power spectral density measured with towed array at a speed of 6.4 kn.

measurements were repeated on Thursday, 25th by operating the array as a vertical array. The projector was let down by a crane from RV ELISABETH MANN BORGESE.

Due to an approaching storm over the North Sea it was decided to leave Sognefjord a day earlier that planned. RV ELISABETH MANN BORGESE started the return journey to Kiel on Thursday, 24th at 7 p.m.. It entered the harbour of WTD 71 (on the former area of the Naval arsenal) in Kiel on Sunday, 27th, at 10:15 a.m., where it was unloaded until Monday, 28th. A time schedule of the research cruise *Nov*EMB*er*2016 is given below:

Date	Habour	Leaving	Launching (started)	Config.	Runs	Recover (finished)	Entering
17.09.	Kiel	1900		-	-	-	(0750)
18.09.	-	-	-	-	-	-	-
19.09.	-	-	-	-	-	-	-
20.09.	Høyanger	-	1405	system test	9		1700
21.09.	Høyanger	0730	0845	self noise	19	1610	1650
22.09.	Høyanger	0730	1047	self noise	10	1430	1640
23.09.	Høyanger	0730	0840	calibartion	5	1550	1640
24.09.	Høyanger	0730	0850	calibration	14	1445	1550
	Høyanger	1900	-	-	-	-	-
25.09.	-	-	-	-	-	-	-
26.09.	-	-	-	-	-	-	-
27.09.	Kiel	-	-	-	-	-	1015

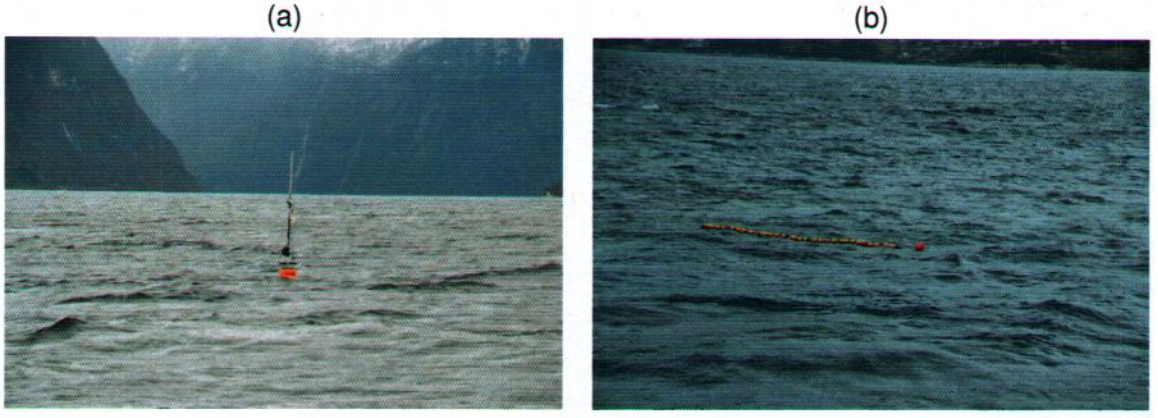

Figure 4: Freely drifting projector buoy: communication buoy (a) and submerged electronic unit beneath floating elements (b) in Sognefjord during operation. Both units are connected by a cable of about 50m length.

All proposed scientific issues including sensor calibration with a freely drifting projector buoy have successfully been addressed during the research cruise. The shortened measurement time due to the early departure on Thursday, 24th has been compensated by a tightened measurement schedule. In total 57 measurement runs have been performed with five different configurations in the period from 20th to 24th of November 2016.

12 CTD measurements

Any hydroacoustic measurement requires a profound knowledge of the sound propagation conditions. Therefore, the sound speed profile is measured with a CTD probe. The sound speed profile enters directly into the calculations of sound propagation, for instance, for sensor calibration. Furthermore it allows the location of the thermocline.

With CTD measurements of the sound speed profile the stratification of Sognefjord has been measured at six different stations during the research cruise *Nov*EMB*er*2016. Five of these stations were located in central Sognefjord south of Høyanger and measured on successive days from Sunday, 20th, to Thursday, 24th. On Wednesday, 22nd, an additional CTD measurement was performed at about 10 nm westward from this position in order evaluated the spatial variability of the sound speed profile in the measurement area. The exact time, position, and depth of the CTD measurements are given below:

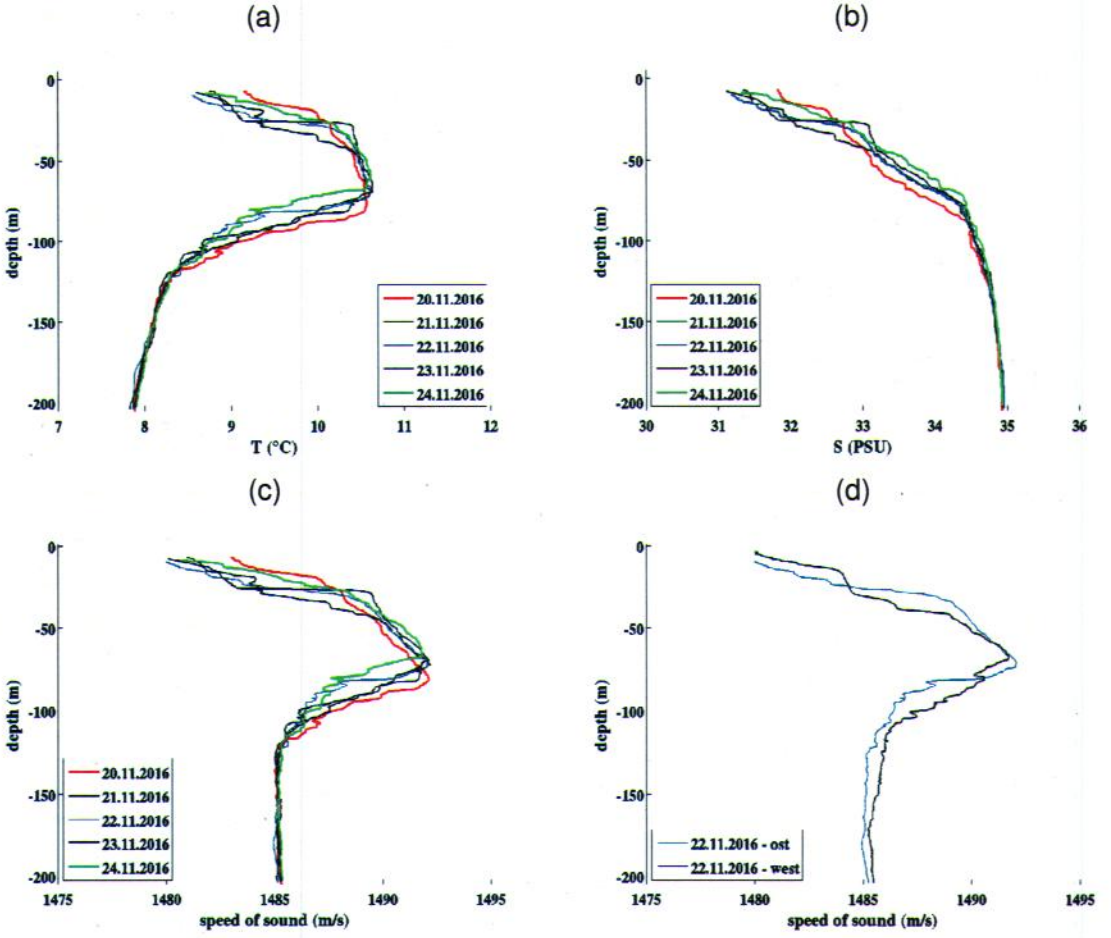

Figure 5: Stratification of central Sognefjord (south of Høyanger) during the research cruise *Nov*EMB*er*2016: Temperature (a), salinity (b), and sound speed (c). Sound speed in the western part of the measurement area on November, 22nd, in comparison the corresponding profile from (c) in central Sognefjord (d).

Date	CTD Station	Time (UTC+1)	Position	Depth (m)	$\bar{c}$ (m/s)
20.11.	0001	14:14:17	61 08.5124N, 5 54.4829E	471.00	1486.91
21.11.	0002	08:08:44	61 08.7221N, 5 59.4264E	201.50	1486.60
22.11.	0003	08:07:22	61 08.4161N, 6 00.9610E	201.75	1486.57
22.11.	0004	14:39:04	61 07.5430N, 5 40.7438E	201.75	1486.69
23.11.	0005	08:13:54	61 08.5468N, 5 59.4154E	201.25	1486.61
24.11.	0005	08:10:11	61 08.4333N, 5 59.9218E	200.50	1486.57

In Figure 5 the five different profiles of each quantity, temperature (a), salinity (b), and sound speed (c), are shown. They were recorded in central Sognefjord. A weak variability can be found for each quantity in the water layers above 120m, which is the lower boundary of the

thermocline, while below the thermocline no significant variability exists. Qualitatively the profiles are very similar for each the three quantities. A comparison of the sound speed profiles measured at two different positions on Wednesday, 24th reveals a small difference is sound speed even below the thermocline. In general the differences in sound speed are quite small between the two measurement positions.

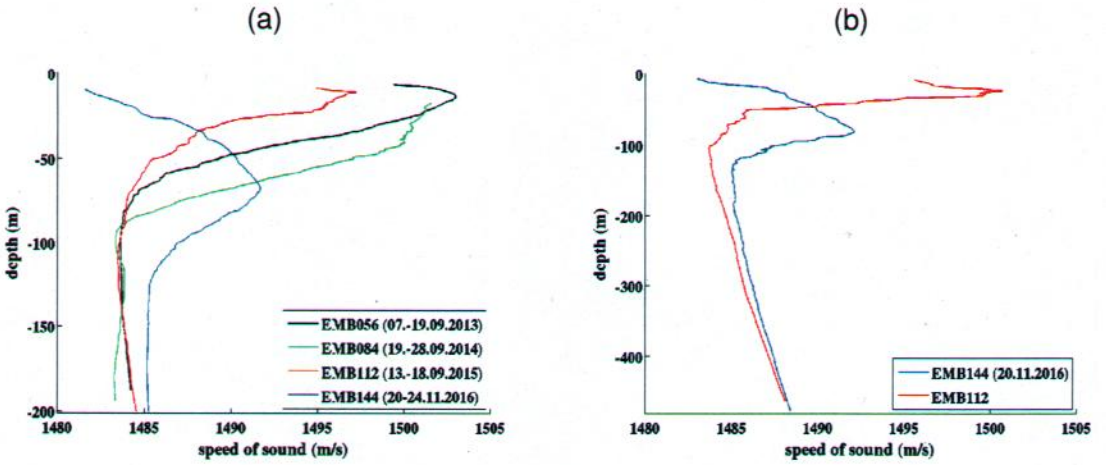

Figure 6: Comparison between average sound speed profiles from four research cruises between 2013 to 2016 (a). Comparison of two deep water profiles of sound speed. EMB112 was conducted in September 2015, while EMB144 in November 2016 (b).

The sound speed profiles measured during *Nov*EMB*er*2016 differ qualitatively from those recorded in the previous research cruises *yellow*FLAME2013 [1], *blazing*FLAME2014 [2], and *cool*FLAME2015 [3], which were all conducted in September, i.e. about two months later in the year. The average sound speed profile of each cruise is plotted in Figure 6 (a). In November the thermocline is lower than in September and the sound speed below the thermocline is slightly larger.

A comparison of deep water profiles depicted in Figure 6 (b) reveals that sound speed equalise below 450m. The most striking difference between the profiles in November and September is, that a surface sound channel penetrates down to a depth of about 70m in November, while in September this effect is strictly bounded to the upper layer of about 10 to 20m depth.

Acknowledgements

The support from Captain U. Scholz and all members of the crew of R\V ELISABETH MANN BORGESE was again excellent and is gratefully acknowledged.

References

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[2] J. Abshagen, Cruise Report, r/v ELISABETH MANN BORGESE, Cruise-No. EMB084_Abshagen (2014)

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[4] J. Abshagen and V. Nejedl: *Towed body measurements of flow noise from a turbulent boundary layer*, J. Acoust. Soc. Am. **135** (2), 637-645 (2014).

[5] J. Abshagen, D. Küter and V. Nejedl: *Flow-induced interior noise from a turbulent boundary layer of a towed body*, Advances in Aircraft and Spacecraft Science 3, 259-26 (2016).