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ON UNDERWATER THINEWALLED MAGNETOSTRICTIVE LOW FREQUENCY DEPTH INDEPENDENT SOUND TRANSDUCER SOURCE EFFICIENCY ESTIMATES

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INTRODUCTION

Free flooded ring core magnetostrictive transducers are frequently used in ocean hydroacoustic experiment [1].Being used as resonance sound radiators they poseses a raw of advantages , such as robustness , wide depth immersion potential , low electric impedance wich means not high driving voltage and , as a consequence , reliability , in comparison to other conventionally used transducers.But when one will try to use them in frequency range below 1 kHz , especially interesting for long range hydroacoustic systems , say ocean tomographic systems , then dimension and weight of corresponig sound sources increase and as a rule became unacceptable. Thus , the main purpose of the paper is to show the way of achieving low enough resonance frequency of magnetostrictive ring transducers without increase of their weight and diameter [3].

THINEWALL RING TRANSDUCERS

Calculations

Widely known expression for resonance frequency of radially vibrating freely flooded in the medium with ambient density quite small to be compared to core density , say air , ring core [2] , could be written in the form:

$$f = (2\pi R)^{-1} \cdot (E/\rho)^{1/2} , \qquad (1)$$

where f - resonance frequency , R - core mean radius , E and ρ - core material Young modulus and density respectively.It looks like - the only way to reduce f is in core radius increase , but it is not so for radiator intensively interacting with ambient medium.If core would be immersed into medium with core comparable density then resonance frequency could be corrected due to so called adjoined fluid covibrating mass influence to give new expression for core resonance frequency f_1 in immersed position :

$$f_1 = (m/m+m_s)^{1/2}\ f\ . \qquad (2)$$

It is obvious from (2) , that considerable resonance frequency reduction could be achieved also by increase , in reasonable limits , of (m_s/m) value in (2).This possibility could be easily outlined for thin ring core as follows.According to calculations performed in Acoustics Institute (Dr. V.Vasilyev) , adjoined mass value of an infinitely thin ring of rectangular crosssection , radiating into medium of density ρ_s could be expressed in the form:

$$m_s = 2\ \pi^2\ R\ (h/2)^2\ \rho_s\ , \qquad (3)$$

for the case where ring core height h is small enough to be compared to R.With aid of (3) expression (2) now takes the form:

$$f_1 = [1+(\pi/4)\ (\rho_s/\rho)\ (h/t)]^{-1/2}\ f\ , \qquad (4)$$

valid for h<R and t<<h , where h is ring cores crossection thickness.Both mentioned conditions being used in reasonable limits are of course of equil importance for proper use of (4).They were used in not presented here derivation of adjoint mass expression (3).Thus , thin wall core ring radiator allows the way of resonance transducers frequency reduction not recoursing to substantial core radius and mass increase.Numerical examples show , for instance , that metal ring of rectangular crossection with $(h/t)=10$, radiating in water in conditions $(m/m_s)\sim 1$, will have resonance frequency 30% lower then in air , while with $(h/t)=100$ - 70% lower.Of course , shown above principal possibility is not enough for transducer design.The most important thing to obtain is practically observed efficiency of sound radiation wich could be predicted and shown exclusively by experiments.

Experiments

Experimental tests of expression (4) was performed by means of magnetostrictive rings - model transducers series.All rings were of equal inner radius (R = 100 mm) , various height h and thickness t .Ring cores were all designed of looped around 0.15 mm - thick textured nickel-cobalt alloy (NiCoMn 4-1) ribbon.To ensure core construction rigidity ribbon winding turns were cemented together by special glue layers of approxmately 0.04 mm thick.Then necessary drying and polimerization process was carried out during 3 hours at 150°C.Electric wire wraped around such core was used not only for heating the core to be polimerized but for it's vibrations electomagnetic excitation as well.Experimental transducers (samples) parameters - h , t , m - are presented in Table 1 together with expected (calculated) values of m_s , f , f_1 for the case of radiation in water. Experimental values of f and f_1 were measured directly on the basis of each transducer frequency behavior by means of : outer core surface vibration displacement amplitude in air and sound pressure at 1,5 m distance from transducer in water registration respectively.Measurements were made for same constant values of excitation and biasing currents.The latter was choosen to be close or equal to coreforming alloy optimum magnetic field ($H_0 \approx 1,2-1,5$ kA/m).Using results presented in Table 1 one could easily compare theoretically predicted resonance frequency values given by expression (4) with experimentally obtained.First of all the same f_s on h/t dependence behavior character is easily confirmed and shown in paper [3] for f and f_s data respectively , but nevertheless precise graphycal analysis shows that some deviations from inverse square root function (4) could be observed , especially in Table 1 last line , for large h/t values.It is not surprising however for inthat case core height h is approximately of an order of radius R and , thus condition h<R required by theory is already not met.while for smaller rings heights theory-experiment coincidence is satisfactory and lies in the limits of 10% which is close to measurements systimatic errors expected.Next important question to be answered is practical radiation ability of transducers proposed.

Table 1

sample number	h , mm	t , mm	m , kg	m_s , kg	h/t	f , kHz	f_1 , kHz
1	35	0,75	0,147	0,604	46,6	6,4	2,83
2	35	2,25	0,440	0,604	15,5	6,4	4,16
3	35	3,00	0,586	0,604	11,6	6,4	4,49
4	25	2,00	0,274	0,308	12,5	6,4	4,41
5	50	2,00	0,559	1,232	25,0	6,4	3,58
6	200	2,00	2,235	19,72	100	6,4	2,04

Low frequency hydroacoustical radiators

On the basys of preliminary calculations and model experiments two magnetostrictive thinwalled ring core transducers were designed and constructed to be tested as hydroacoustical radiators for ocean tomographic system.Their parameters are presented in Table 2. Radiators cores were manufactured of 0.15 thick nickel-cobalt alloy ribbon by the same technology as used for experimental model cores described in previous section.Corresponding wire windings were feeded from conventional a.c. power generator providing vibration excitation , permanent magnets biasing system was designed to be constructively combined with core fastening utility of the radiator , where magnets of the type UNDK 35 T5BA were used.Values of resonance frequencies and radiated acoustic powers were esteemated by direct multipoint ocean measurements of radiated sound in conditions close to expected for stationary CW tomographic system with almost stationary transducers installation on sea bottom feeded through cable from the research ship or from the shore.Test period of each radiator was not less then 3-5 days and ,thus two last columns of Table 2 show experimental period averaged data.Measured values for two radiators were obtained for the same immersion depth 150 m in one of Barentz sea regions used .Nevertheless both radiators were additionally tested on various depth , between 50 to 300 m , where expected stability and efficiency was observed as well.It is useful to underline weak dependence of resonance frequency and emitted power on depth noticed in experiments.Estimated efficiency on resonance frequency was approximately 40% and up to 30% in the frequency band of approximately 10% width [3].

Table 2

sample number	2R , m	t , mm	h , m	m , kg	f , kHz	f_1 , kHz	W_a , kWt
1	1,0	7,5	0,25	120	1,20	0,470	1,00
2	1,5	6,0	0,50	150	0,90	0,220	0,20

CONCLUSION

Thus it is shown that thinwalled resonance magnetostrictive ring transducers could be especially convenient for ocean exploration purposes, for instance, when used in CW tomography systems due to their reliability, robustness, deep water operation potential and low electrical impedance. They could be used even in the frequency range below 1 kHz and their dimensions still remain quite modest to be compared to conventionally use ring transducers.

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