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Mitigation of Underwater Vibration Due to Offshore Wind Turbines

S. Sowmiya[1]
Department of electrical and electronics engineering
Parisutham Institute of Technology and science
Thanjavur

ABSTRACT:In this modern world, the demand of electricity is drastically increased. Therefore, we are in the need of abundant electricity.At the same time, we need concern about the environmental impacts due to conventional energy resources.Thus the technique of power generation from renewable energy resources evolved. Power is generated from wind energy because no co2 emission is involved in this process.In order to increase the efficiency of wind power generation ,it is moved towards the seashore.Thus the offshore wind turbines are evolved. But major impact of offshore wind farm is underwater noises and vibration.Becauseof this vibrations, marine ecosystem is disturbed.Especially marine mammals are affected. These animals are driven away from feeding or breeding grounds, loss of communication among the animals, deflect from migration route.In this paper, we offer a damping technique to reduce noise and vibrations in underwater. we prefer to use a thermoset , polyether-based polyurethane material which has superior damping coefficient. It exhibits the property of viscoelasticity which means elastic solid at rest and converts energy's frequency into heat.Therefore by using this material we can avoid vibrations in underwater.Therefore we can save marine animals from unwanted disturbances due to vibration.

I. INTRODUCTION:

Offshore wind energy is a kind of wind farm constructed in water bodies especially in ocean. In offshore wind speeds are very high compared to land, so offshore wind power generation is higher per amount of capacity installed.These wind farms have very low global warming potential per unit of electricity generated.Because of its high wind speed energy can be produced at given moment.Fewer turbines are required in offshore wind farm to produce similar amount of energy as onshore farms.It is a additional kind of energy source along with onshore wind farm to boost up the renewable energy resource to generate electricity.The wind turbine foundation may act as artificial reefs, providing surface to which marine animals attach.Even though there are several environmental impacts are arises due to offshore wind farm. The major environmental impact concerned in this paper is vibration and noise of offshore wind turbine.These vibration and noises affects regular habitat of marine animals, alteration of food web.Pile driving is a commonly used method to secure turbine foundation to the sea floor.The loud sounds emitted during pile driving could potentially cause hearing damage,displacement of animals to avoid noise.There is also risk to marine mammals, sea turtles, and fish are disturbed during surveying and installation activity.Therefore we need to use vibration dampers to avoid environmental impacts.We can use polyether based polyurethane material as damping material because of its superiordamping coefficient.

II.SOURCES OF VIBRATION IN OFFSHORE WIND TURBINE:

1.1 Pile driving:

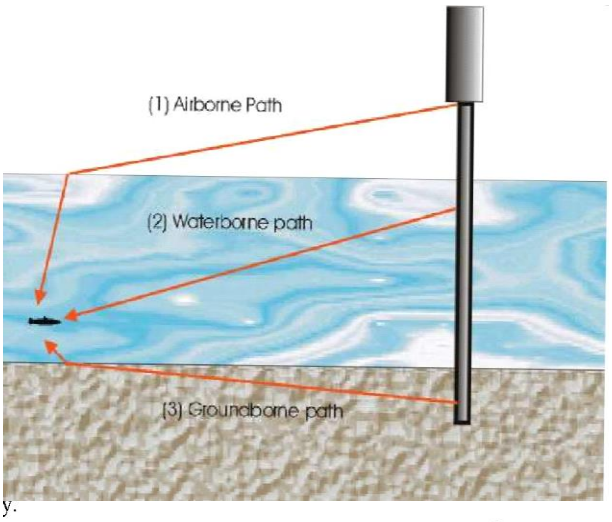
A pile driven turbine foundation involves forcing a hallow cylindrical steel tube into soft ground to such a distance that it provides a suitable foundation to build a wind turbine.The dimensions of steel monopiles approximately 4 meters in diameters and 20 to 30 meters long. A number of pile driving noise taken of piles ranges from 208 mm to 1m on increases with increase in diameter.Source level of upto 215 dB re 1 microPa @1m for impact pile driving.

1.2Drilling:

Drilling is a process of installation of wind turbine pile foundation in conjunction with pile driving.The range of source level vary from 145 to 195 dB re 1 microPa @ 1m. No measurements are available for shallow water drilling.

1.3Wind turbine operation:

During the operation of wind turbine, the turbine blades will generate aerodynamics as they pass through the air which may enter water via anairborne path. Aerodynamics noise will increase with increasing rotational velocity of turbine. The hydrodynamics forces from passing waves will induce structural vibrations. The greatest exposure on marine environment is mainly dueto wind turbine operational noise.For low power wind turbines (<1MW) shows sound level of low frequency upto 153 re 1 microPa.



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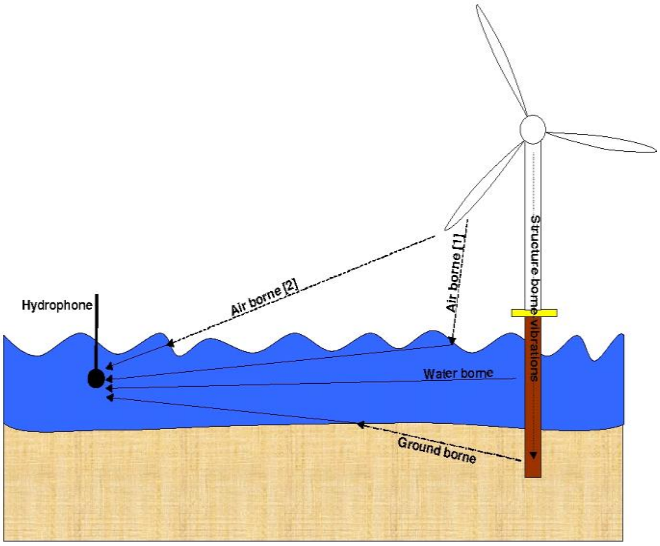


2.VIBRATION AND NOISE MITIGATION METHODS:

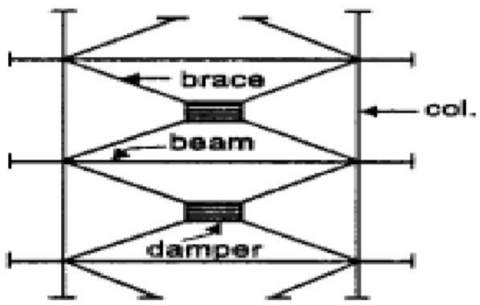
Structural control systems are used to mitigate unwanted vibrations generated in turbines . They can be designed in number of forms.There are active , passive and semi-active systems.In these systems, active and semi-active systems utilize feedback control to improve the vibrations reduction of structure.Passive systems are typically tuned to a certain frequency of a particular structure for vibration mitigation.This paper will fully turbine.

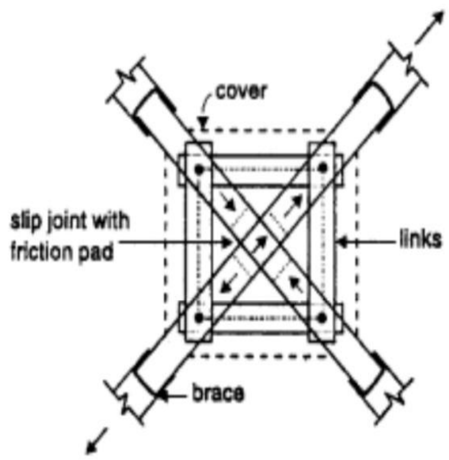
2.1 PASSIVE STRUCTURAL CONTROL:

The simplest form of structural control device uses no external energy to reduce vibration imposed on the main system is known as passive structural control.A key benefit to passive control is that once installed in structure , they no need any startup or operation energy unlike active and semi-active systems.Passive systems are active at all times until maintenance, replacement or dismantling is required.There are many different types of passive control systems are examined in this paper.Some structural control system do not contain spring like component and are not tuned to any particular natural frequency. This type of nature passive structural control system includes friction damper ,the metallic yield damper and the viscous fluid damper.

2.1.1 FRICTION DAMPER:

Friction dampers are a type of spring less damper system. They consists of two solid bodies are compressed together. As a structure is subjected to vibration , the two bodies slide against each other , developing friction that dissipates the energy of motion. These devices have been developed in structures and have been successful at providing enhanced seismic protection by being designed to yield during extreme seismic vibrations. Wind loads do not provide enough shear force to activate these type of dampers. Though they are reliable at reducing seismic loading , they are not designed to slip during wind loading and they would not prove effective in a floating wind turbine.





2.1.2 METALLIC YIELD DAMPER:

A typical design of this damper is triangular or x shaped plate that absorbs vibrations through the inelasticitydeformation of the metallic material.These devices are known to have a stable hysteric behavior and long term reliability.These type of dampers are usually installed in newly built and retrofitted buildings.They are successful in reducing seismic loads.

2.1.3 VISCOUS FLUID DAMPERS:

Viscous fluid dampers(VFD) are another type of spring less damper system .Similar to shock absorber , they consists of a closed cylinder piston that is filled with fluid usually a type of silicon oil. Fluid can move between chambers of the piston.

2.1.4 COATED TUBE AS SOUND BARRIER:

A noise barrier based on solid material between the barrier material and water is a passive noise reducing method. In the Baltic sea a foam coated tube of 2.2 m diameter was put over a pile. The tube of steel and the coated foam material layer of 5mm are discontinues on the transmission path of the traveling sound waves ,passing through the barrier of different material strongly depends on the material different products of sound velocity and density .Each transmission of waves from one material to another and into water is accompanied by reflections and energy lost with the effect of reducing acoustics noise emission into the water . A steel tube alone or a rubber layer only show small noise reduction but with foam coated steel tube noise reduction of 5 to 25 dB

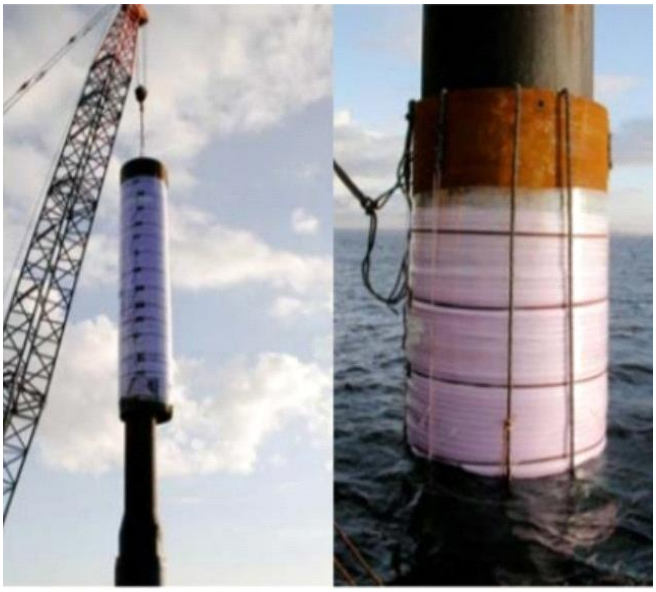
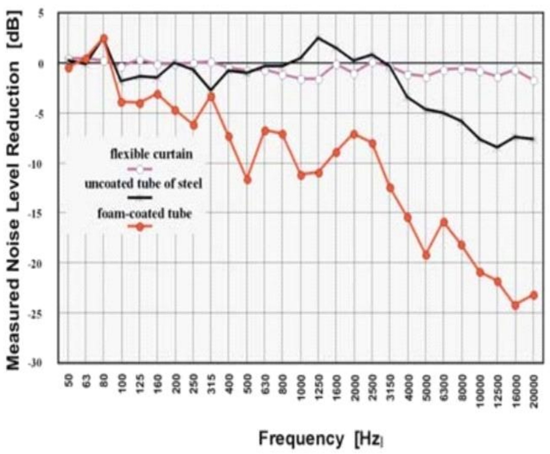
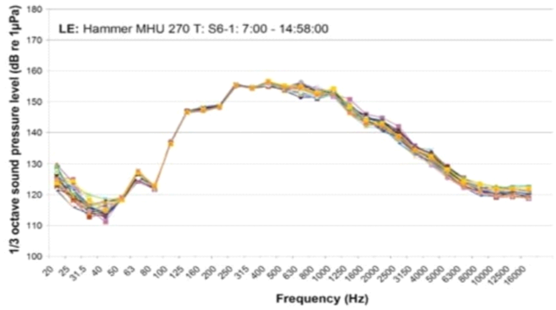


Fig : coated tube over a pile in Baltic sea

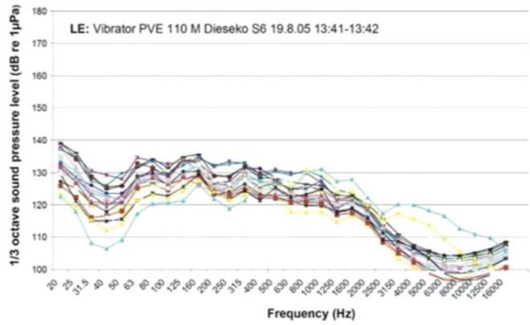


2.1.5 VIBRATORS FOR SMALL PILES:

The primary noise reducing method is using unbalanced vibrators for pile driving of small piles into appropriate ground instead of using hydraulic hammer induces under water noises in large frequency range of up to several thousand hertz. Unbalanced vibrators operate with continuous vibration of frequency between 20 , 40Hz.Within this frequency range mammals do not react very sensitively. The noise reduction during pile driving using vibrators is about 15-20 dB



Noise spectrum of an impact hammer



Noise spectrum of a vibrator.

But pile driving using vibrators is limited to certain soil and small piles.

III. MEASURED UNDER WATER NOISE:

Measured sound pressure of a single stroke.

Measured Noise Emissions: Object	Pile diam. [m]	Energy [kNm]	Lpeak [dB]	LE [dB]
Port construction, coast	1.5	280	184	158
Monopile Sky2000, Baltic S.	3.0	280	185	164
FINO1 (Jacket), North Sea	1.5	280	189	164
Monopile Amrumbank, N.Sea	3.5	800	200	175
5 MW – OWEC (expected)	6.0	600	>205	>178

Tab. 1: Measured pile driving underwater noise emissions at a distance of 750 m.

The underwater noise emission of offshore pile driving during construction of different objects in table 1 are measured at a distance of about 750 m.

Peak sound pressure level of ;

Lpeak > 180 dB re 1mPa

Single event sound of levels of

LE> 160 dB re 1 mPa

These are potentially harmful to marine animals and other marine mammals.

IV. ACOUSTICS AND VIBRATION CONTROL OF UNDERWATER STRUCTURE:

Acoustics and vibration control for an underwater structure under mechanical excitation using negative feedback control algorithm.Underwater structure may be cylindrical, conical or circular shells.Acoustics property is analyzed by Helmholtz integration formulation with boundary element method. Based on negative feedback algorithm , controls loop with acoustics piezoelectric sensor; accordingly the active control of structural vibration and acoustics response are analyzed.

In order to absorb the sound energy transmitted through the structure is concerned with coating of sound absorption is a viscoelastic material.Interfacial problems may arise due to coating with substrate such as stress concentration , thermal stress discontinuity and delamination. To avoid these interfacial problems core should be made of (FGM) functionally graded materials.

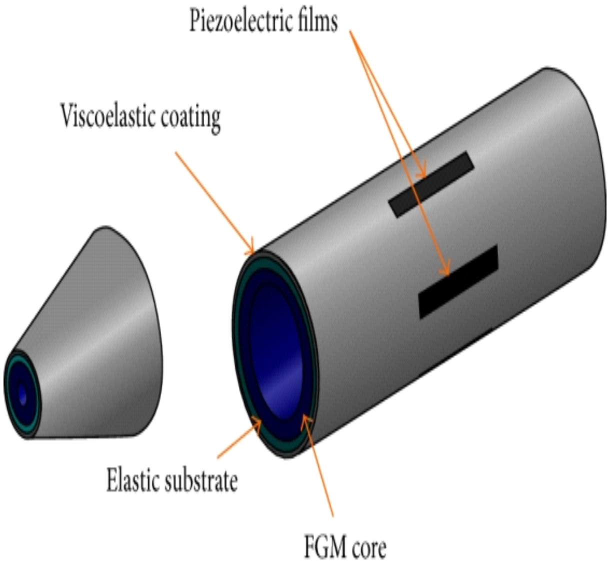


Fig: Schematic diagram of underwater structure with piezoelectric films for acoustics and vibration control in offshore wind farm.

In this paper I considered the underwater structure as offshore wind farm with monopiles foundation.

Geometric size of underground structure(Monopiles foundation):

Parameters.	values
Diameter	3.5 to 4.5 m
Pile length	10 to 20 m
Coating thickness	0.025 m
FGM core thickness	0.015 m
Length of piezoelectric film	2.0 m
Width of piezoelectric film	0.4 m

With the reference of research article , "Acoustics and vibration control for underwater structure under mechanical excitation"[1] the following process are carried out. It is a passive noise control technique such as sound and vibration insulation. The high frequency could be repressed by adopting stiffened material with high damping ratio. The vibration and acoustics control for under water structure is obtained by applying negative feedback control algorithm.

A geometric model is built according to the reference (Caresta and Kessissoglou[11]) in the present analysis on the acoustics and vibration control of an underwater structure(Monopiles foundation of offshore wind turbine).There are three laminated layer , namely the elastic substrate , FGM core and viscoelastic coating . Four pair of piezoelectric film are attached to the inner and outer surfaces of the cylindrical shell .

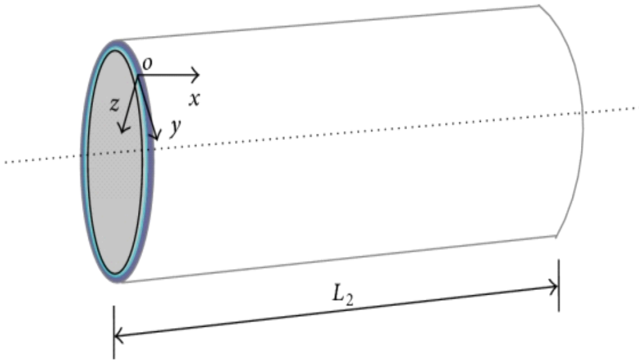


fig: cylindrical structure of monopiles foundation

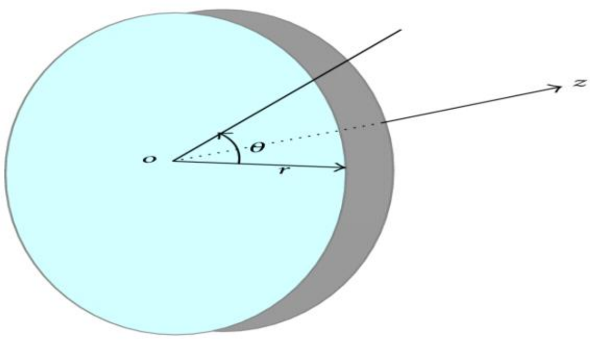


Fig: circular bottom structure.

The direct and inverse piezoelectric effects are considered as sensor and actuators.

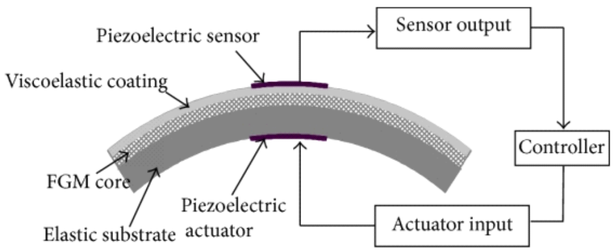
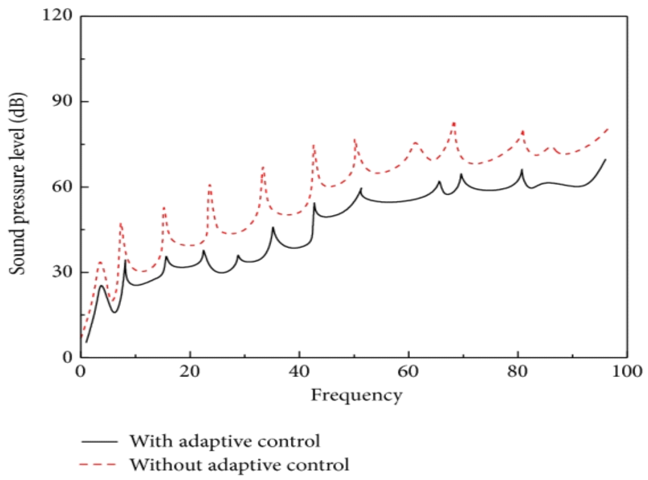


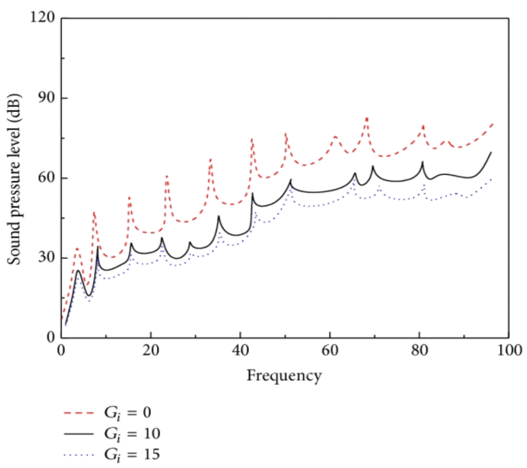
Fig: schematic diagram of piezoelectric control loop

The sensed potential is proportional to the vibration amplitude with the negative feedback algorithm and has an effective control on structural vibration of underground structure. The vibration amplitude is decreases by the negative electric potential. Due to energy dissipation of the coating's viscoelastic property , the dynamic response of the underwater structure on the center of cylindrical shell is little small and the frequency also decreases.

The below graph shows the frequency variation according to the adaptive control to the underwater structure. It shows the frequency decreases when adaptive control is applied to the system.



The below graph shows variation of sound frequency based on the gain (Gi)obtained in the control loop. It estimates that the gain(Gi) increases in negative control loop sound frequency decreases.



4.1 VISCOELASTIC MATERIAL:

The main aim of this paper is to reduce the underwater vibration and noises arise due to offshore wind turbines. In the above research article of "Acoustics and vibration control for underwater structure under mechanical excitation"[1] , viscoelastic material is used to absorb the generated sound waves. Viscoelastic material is used as vibration damper. In this paper I suggested a viscoelastic material with superior damping coefficient namely polyether based polyurethane material generally known as Sorbothane. It exhibit enhanced viscoelastic property that is , it performs like a liquid under load and as a elastic solid as when at rest.It is fabricated specially to use as a damping material.

4.1.2 SORBOTHANE AS A VISCOELASTIC MATERIAL:

Sorbothane is the best damping material for the following reasons.

It absorbs upto 95% of shock energy and more than 50% of vibration energy for millions of cycles.

It performs across frequencies from 10 to 30,000 Hz.

It performs across temperature from -20 deg to 160 degFahrenheit (-29 deg to 72degCelsius).

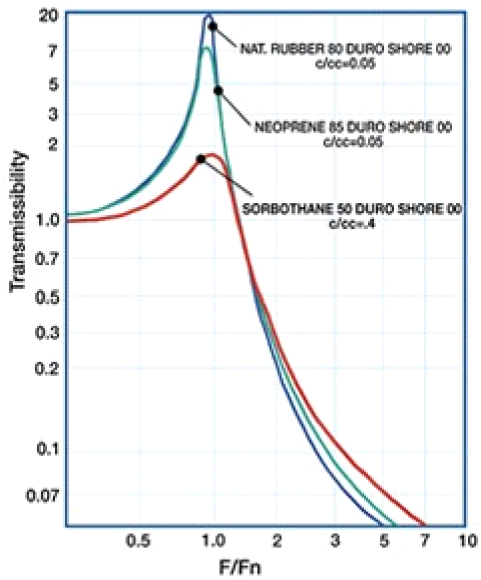
It can be easily fabricated or modified to any shape,size and thickness.

It has high damping coefficient will attenuate the response that is it "swallow the energy" and reduce the reaction of the system.

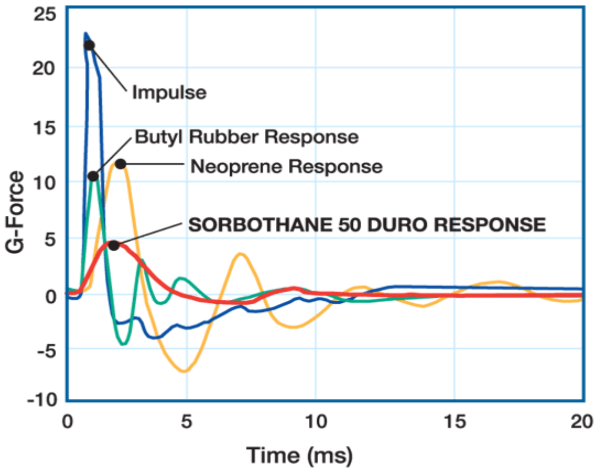
It as a good vibration isolation system because it will reduce the natural frequency of a mechanical system below the excitation frequency.

It is water resistant material and with reference of article "accelerated ageing of polyurethanes for marine application"[2] therefore it is the most suitable viscoelastic material.

Therefore it can be used as vibration control in monopiles foundation of offshore wind turbines.



The above graph shows the transmissibility T of Sorbothanematerial. When T>1 maximum amplification occurs in the system, but transmissibility of Sorbothane is 1. Therefore it is very suitable to act as a vibration damper.



Time Delay Effect of Impulse (Shock) Response of Selected Materials

The above graph shows duroresponse of Sorbothane material.Duroresponse is the measure of hardness of rubber material.From the graph it is infer thatSorbothane has less duroresponse compared to other viscoelastic material. Hence it can act as good viscoelastic material.

V. CONCLUSION:

The method of acoustics and vibration control of under water structure using Sorbothane as viscoelastic material for vibration mitigation technique in offshore wind turbine is more efficient than mitigation technique. It is suggested to be most efficient technique because of its superior damping and viscoelastic property.Hence by using this technique we can control underwater vibration of offshore wind turbine in wide range. Thereby we can avoid environmental impacts in sea and we can protect marine animals from unwanted disturbances.

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