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NOISE & VIBRATION 141107

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Chairman— Martin Redmayne

Alright, I ask Reza and Mathieu to join us on the stage to talk about a fairly interesting sort of counter subject, Noise & Vibration.

Dr Reza Kashani Deicon Inc

Good afternoon. Today I am going to go ahead and talk a little bit about isolation of diesel generators. Rob made a very good introduction in terms of talking about the importance of noise and vibration reduction; it's very very important for a lot of marine applications, especially superyacht and luxury marine applications. And towards the end of the talk I will talk a little bit also about the room acoustics, cabin acoustics, and at the end try to put these two together.

Well, why do we need isolators? No, Rob couldn't have said it better. He said that quiet, no vibration, is what we really need to have and machines, any machines, including diesel generators are perturbed by vibration of their own working and they are also perturbed by shocks. As a diesel generator operates, it operates at a constant rpm all the time and because of that, it generates vibration force at frequencies corresponding to the harmonics of that rpm. A diesel generator operating in Europe has the lowest frequency at 12½ hertz, if it's a 1500rpm, and then it goes in multiples of that frequency and it always stays at those frequencies. So as you can see, the vibration signature is very much tonal and it appears at certain frequencies and you know those ahead of time. Starts at very low frequency, about 12½ hertz and goes to higher frequencies. But at the same time vibration is not the only thing that perturbs the machine. You can have a wave hitting the ship, so the hull can go through a shock type input. That sends the perturbation to the machine as well. Sometimes you turn the machine on and off, that sends also a shock type perturbation to the machine. So we need to reduce the transmission of vibration and shock to an acceptable level and because of that we need isolators. These two cartoons sort of show both the transmission of vibration force from the machine to the base or the hull and vice versa. The transfer of shock type perturbation from the hull back to the engine, to the machine. And in both these two cases you want to make sure that the machine doesn't move a whole heck of a lot either. So the transmission of force is important, the motion of the machine itself is also important and the isolator has to really do good in both of these two cases. Now the reason diesel generators are a little bit different from the propulsion engines itself is that the operation of the diesel generators requires different expectations, if you will, on this shock and vibration isolation. The most common practice in doing isolation for diesel generators is using elastomeric material. It's very affordable, either natural rubber or neoprene is being used widely, they can be arranged either in what they call single stage mounting, very simple, you put the machine on one set of mounts and the mount sits on the foundation, the hull, on the structure of the boat, or you can do two stage mounting, which is what you can see here. There are two sets of mounts, the machine sits on the first set then you put some sort of auxiliary mass in between and then the auxiliary mass sits on the second set of mounts, and the second set of mounts sits basically on the hull, on the structure of the boat. So you have this auxiliary mass if you go with this second arrangement to a stage mounting. So it's a little bit more involved, a little bit more complicated and because of that there had better be something in it otherwise why bother? Well, I don't want to get too technical here but one of the metrics that we normally use as I mentioned earlier to judge whether we are doing good in isolating a machine is looking at how much of that force of vibration gets transmitted to the base. We call this parameter—I'm just going to throw jargon in here—transmissability. In other words, how much of the vibration is ending up in the structure of the boat. Well you want that to be as small as you can get away with. Here I have their traces, let's start with the black one first. Black one is for a very simple, single stage mounting. As you can see, once you go beyond 12½ hertz the frequencies that are of interest to diesel generators, the valley of this transmissability gets smaller and smaller and smaller as you go to higher and higher frequencies. And that's pretty good. The blue trace shows what you can gain by going through two stage mounting. Well, it makes it a lot better at higher frequencies and to bring this a lot better aspect further down to frequencies, in other words changing the blue trace for example to the red trace, what you need is more mass, more auxiliary mass that is, being used in the arrangement in the set up. So here the blue trace is something like the auxiliary mass being 10% of the mass of the machine itself, and the red trace is when the auxiliary mass is about 25% of the mass of the machine. So definitely it does some good in lowering the transmissability, you feel less of the vibration especially at higher frequencies but there is this weight penalty and the previous presenter definitely emphasised the importance of weight reduction nowadays. There's a lot of importance on it, you don't want to have any extra mass if you can get away with not having it.

So with that background, let's talk about another possibility in terms of mounting diesel generators, and that's using air. Well, the best way of mounting if we could, I'm not saying we can, but if we could, would have been just leaving the diesel generator up in the air, thin air. That's a little difficult to do, so the next best thing is perhaps putting it on contained air, a cushion of air, if you will. And that's what air mounts are. It's a little difficult to see but that little ugly black thing there is that cushion of air that I'm talking about. The word *adjustable* is highlighted because it's a very very important aspect of air mounts and I'll come back to it again later on. As opposed to elastomeric mounts air mounts can be played with once you put them under the machines, whereas you cannot do that with elastomeric mounts. Once you put the elastomeric mounts there, that's it. You can't change anything, any aspect of that mount. Whereas air, you can go ahead and make it stiffer, softer, more damp, less damp, all kinds of things. So adjustability is a very important thing and we are banking on that aspect of air. There are other good things about it. The main thing is you can do soft mounting, in other words the mount can be soft and yet not be very large in size. Here an air mount is being compared to a traditional spring for the same stiffness, or softness, I should say, a traditional spring be it metal or elastomeric would be a lot larger. So if you use air mounts you can get away with using a smaller design heights, better design, and still have the softness which is needed to do a good job isolating the diesel generator. This is another design, it's also commonly available. The first design is called convoluted air mounts, the other design is called pneumatic air mounts, I don't know why they called it pneumatic air mounts but it has a little more lateral stability if you go for the other design. But nevertheless both of them really trap enclosed air to provide suspension. OK another one of those squiggly lines. Well I'm borrowing two of the traces from the previous plots; the black trace is just a single stage elastomeric mounting; we talked about that before. The blue trace is a two stage mounting, still elastomeric, with the mass of the auxiliary being about 25% of the mass of the machine. And the red trace is using air. Well, if the metric requires that the lower is the better, you can see that the air is doing pretty good. Especially at lower frequencies. The frequencies that you can sort of feel with your feet on the floor. The frequencies that creep up easily through the structure and end up in the cabins, low frequencies. And it's not doing all that badly at high frequency either, definitely better than single stage mounting and reasonably close to double stage mounting. So altogether we believe it's a very good approach to mounting.

Now I said all good things about it, is there any disadvantage in it? Well what makes it good is also what makes it bad. If you recall I said at the beginning, in addition to lowering the vibration force being transmitted to the hull, you also want to make sure that the diesel generator itself doesn’t move too much. Especially when shock hits it. When a wave hits the boat. This trace is a little bit different from the previous one. This is really looking at the motion of the machine itself when it's being disturbed by shock. And as you can see, at lower frequencies, air mounted systems move more. I guess that’s to be expected too, because they are sitting on softer cushions. So the softer the cushion is, the more bouncy it becomes. That cannot be very good, especially when the yacht is sailing and the water is choppy. So they are not super when it comes to shock isolation, as good as they are at isolating vibration they are not super in terms of shock isolation and they don’t have lateral stiffness, a whole heck of a lot of it at least. If you push like this on it the diesel generator moves a little bit. So I was talking about using air mounts and air mounting with a colleague and he said well, I experimented with it about 20 years ago and when I turned my diesel generator on and off it looked like a dog getting out of a swimming pool shaking the water off itself. And he was not wrong. It just moves a lot because when you turn the machine on and off you are really putting a shock input to the machine and that makes this wobbly thing move too much. Well, I said that might have been true 20 years ago but this day and age is the age of low cost computers, sensors, high speed servo valves, high speed solenoid valves and elegant control schemes. So it doesn’t have to do that. And that brings us to computer controlled air isolation systems. So we promote air isolation systems realising the drawbacks of it and providing solutions for it. We do this for diesel generators, we are not promoting this for main propulsion engines. The main difference between diesel generators and main propulsion engines is that a diesel generator is not connected to a driving shaft. It's basically just connected to a generator and then you have some hoses and plumbing and all that connected to it. So it doesn’t need to be fixed to the hull. It can move, but you don’t want it to move when it's not supposed to move, in other words when the boat is docked or anchored and you want peace and quiet, the water is calm, what is wrong with having this thing sitting on air being wobbled. There is no shock coming into it,. At night you are sleeping, the water is good, calm, you want quiet, so let it be soft. But if you need that to be stiff you'd better be able to stiffen it up very quickly, you'd better be able to add damping to it very quickly, you'd better be able to go ahead and engage and disengage lateral stiffness to it very quickly. That’s where all those things that I mentioned, computers, high speed valves, controls and all that comes into the picture. And you can achieve all of these things without that weight penalty I was talking about. Remember, weight is very very important, and 25% or even 10% of a multi ton machine is a lot of tonnage. And if you don’t have to use that, so much for the better. And yet not sacrifice anything. In this system the computer monitors the accelerations and then decides what state the machine, the isolation needs to be running at. Should it be stiff, should it be soft, should it be damp, should it be under damped, all of that is being decided by the computer. It will be done very quickly, very automatically. In a sense it's sort of like the airbags in a car. You don’t want to drive with the airbag inflated but if it needs to be inflated then it gets inflated very quickly. It's the same kind of concept. Our system doesn’t get engaged and disengaged that explosively like the airbags do, but if need be it gets engaged and disengaged.

And that sort of brings me to another aspect of my talk and towards the end I put the two together, hopefully. And that’s the low frequency room acoustics. Well you notice I'm emphasising the low frequency very much because it's a little difficult to get around, a little difficult to absorb, damp. With that background let me just appreciate the quiet a little here and say that rooms have resonances and these resonances are very loud and very distinct at low frequency, at the base region. The geometry of the room has a lot to do with these frequencies, and the shape of the corresponding modes. And passive damping, that is sound absorption material like glass fibre, mineral wool, this kind of stuff, they are not very effective absorbing the low frequency sounds. Now with that background, let's say you have a cabin that has a resonance at 50 hertz. And remember one of those tones that diesel generator generates, one of them was 50 hertz. So if that 50 hertz creeps up to that cabin it will be heard very very loudly all the time. So it's very important to damp the resonance and I'm talking about acoustic resonance, not structural resonance of that room. If you sit in that room for a long time you get fatigued very quickly. This is an example of a room that I worked on, it's an office in a particular motor yacht, the desk was in the middle of the room and the occupant had a chair just behind that desk where the sound as you can see was very high in that particular mode at 75 hertz, again, 75 hertz was one of those frequencies that the diesel generator was generating. The frequency response on the bottom shows you that particular resonance, very briefly, very high at that frequency. So that was really bothering the owner. So if you have a problem like that, in one of the cabins or all, or most of them, what do you do? Well if you have already got it, it's probably a little too late to go ahead and change your design of the room but if it is at the beginning of the design process of a particular yacht you'd better pay attention to the dimensions of that room, the size of the room, the geometry of the room. It makes a huge difference if you pick the right size and geometry and proportions. But having said that, we know that there are all kind of structural constraints that the designer is having his or her design subjected to. So how about using a lot of sound absorbing material and trying to go ahead and make that resonance to sort of tame down. No, as I mentioned before, you need a lot of sound absorbing material to be able to absorb a 50 hertz resonance. If you put that much sound absorbing material in that room it probably takes care of that low frequency problem but it kills the high frequency liveliness of that room, and when you're talking in a room like that it's like talking in an anechoic chamber. So you don’t want that. Besides, excessive weight and space penalty of all that sound absorbing material. They need to go somewhere. How about doing an isolation on the diesel generators in such a way that the low frequencies are being isolated as much as possible and that brings me back again to that air isolation system. Soft mounting is really required to address this. And if you want to go ahead and address the room itself, and not using sound absorbing material, is there a remedy there? Well, the answer is yes. If low frequency resonance is what bothers the occupant of that room then it might be possible to go ahead and actively add damping to that room. And I'm talking acoustic damping. It's a device the size of a 10" sub woofer; you put it in the room and then you tune it to that particular frequency and it adds damping to that frequency. The frequency responses here at the bottom shows two of such modes in a room, and this device was tuned to those two modes and as you can see, there are two inner traces that shows that the magnitude of those two peaks have been reduced, in other words damping has been added to that room. So those tones are not as bothersome as they used to be when this device is set in the room and is tuned to those two frequencies. In summary, we talked about this computer controlled air isolation system. With this system, which is really only good for diesel generators, we are not promoting it for main engines you can have what we call an uncompromising isolation system. Any other isolator, you have to compromise on this part or that part, you have to come up with an optimal design that gives you a little bit of everything, not the ideal way of anything. Whereas this allows you to have it soft when you need it soft, have it stiff when you need it stiff, damp, undamp, and all of these things under the control of the computer. What makes it do this, the enablers of this technology, is first the adjustability of the air mount itself. And secondly all these gadgets that I just talked about. Sensors, actuators, computers, all of these things are available at low cost readily these days. It provides beautiful unsurpassed vibration isolation for diesel generators and as I said, it's soft when you need it to be soft, it's stiff when you need it to be stiff, and it basically prevents also the transmission of the very low frequency vibration coming all the way up to the cabins and setting off those resonances corresponding to those modes in the room. Now talking about the room again, you want to make sure that at the beginning when you're designing the architecture of the yacht, you are laying it out and the interior designer is there and all that, make sure you use the right sizes. To a degree you can, for those cabins, and if with all of those constraints you ended up having a room with the wrong geometry, then you just have to go ahead and try to absorb the energy of the sound at the resonances of the room, it cannot be done with passive sound absorbing materials but it can be done with active tune damping of the acoustics of that room. Incidentally that device, that little box I showed you, can also be used as bass traps in home theatres or home cinemas that now bigger yachts are putting into the boats. Any questions?

Martin

Reza, what we're going to do is ask questions at the end of the session so that Mathieu has exactly the same time. Thank you Reza. Mathieu, please?

Mathieu Noé Hutchinson

Ladies and gentlemen, good afternoon. I'm going to show a little bit different approach where I would say we combine a little bit traditional passive approach with new active means and try to come up with a solution that can fulfil requirements regarding propulsion gen sets and other kinds of applications like—also a very interesting topic--today's propulsion induced vibration. So we're going to address these kind of typical vibration noise issues, with using the same common technology core.

The principle is we want to cancel unwanted sound and vibration by simply imposing a compensation signal which has to be exactly in anti phase. So we have to generate a secondary field by actuators like shakers or loudspeakers that will exactly compensate the field that is generated by your engine or by your gen set. We need sensors to monitor the results because it's functioning in closed loop configuration and we need an electronic control unit to make sure that everything is computer right. OK, it's very like a human being where your actuators are like your muscles, your sensors are your senses, sight, feeling, smell and so on and your brain is doing the control unit. Let's go to our first example. Propulsion—here you can see an MTU engine sitting on a test rig on active suspension. These active isolators are a combination of passive elastomeric isolators on top of a box that contains actuators and sensors. This has been proven on the test rig with several foundation configuration, very stiff and heavy, concrete based foundation and also those like double T steel foundations. And in each case the system is functioning perfectly. So basically these kind of active isolators, as I mentioned, is on top passive elastomeric isolator and below in the rigid box you have different actuators working in different directions, depending on your vibration problem. And we have developed a range of actuators that fits almost in any application, ranging from 30 to more than 300 Newtons today. Thanks to the different shapes that we can give to those actuators, we can accommodate any kind of weight or space requirements. The control unit is today based on a ruggedised industrial PC where we have added some of our knowledge into that stuff and we have also developed the algorithm that controls the actuators. Some results from the test bench—earlier results where we had a configuration where we could target 8 engine orders, you see typically on the chart below vibration levels measured on the foundation side, the red spectrum is the vibration that is measured with the system without activation and the blue one is with activation. You can clearly target any kind of engine order; we have selected for this application the orders 2, 3, and so on up to 7, and for all these engine orders you can see the route means the average gain on all the sensors which is typically in the range from 20-25 db, that means between only the passive isolator and the system activated you get a one to more then ten reduction in vibration that is transmitted to the foundation. Another way to look at the data is, the data in the plotted levels are colour coded, so red means heavy vibration level, blue means low vibration levels. You have the different sensor in the XYZ direction and on the X axis you have the different engine orders. That is without control, this is with control, you can see the difference, where the hot spots go down, up to the very low level vibration. And this was for the engine mounting system but we have to expand now also up to the gearbox because the engine is generating vibration that is coming through the coupling system and this vibration from the engine is transmitted to the hull structure also through the gearbox and usually the gearbox is hard mounted or hard elastic mounted, which means it's quite a rigid link also. So we have a sort of fight against that transmission path and in the next project we will do it this way. Gearboxes are typically a problem, either because they are in the transmission path from the engine to the hull structure so they transmit vibration coming from the engine, or they transmit also their own vibration which is the gear mesh frequency. So you can typically hear during a run up test, this whining noise coming from the gears. Here you have an example of a large gear where we're going to introduce an active system or we're going to upgrade I would say the situation by introducing actuators and sensors in the transmission path. We have also tested the system for large E-drives, you can see here a large permanent magnets motor which is used for fuel cell based submarines. It's not a superconductor engine but it does not make sense here anyway. And what we want to control is the vibration that is generated by this motor. Electrical motors can generate vibration because the attraction forces between the rotor and stator generate vibration that can be transmitted also to the hull structure. We have made some experimental investigation on the engine where we have installed actuators and sensors that you can see in these pictures. We have controlled 6° of freedom at each foot and basically the results look quite nice because the imaging tone that you see on the left picture has been reduced by roughly 25db. The chart on the right is these 16 sensors, the levels measured on the sensors without control are the red crosses and the levels measured with control are the blue crosses. So you can see that the reduction is quite effective and you get a more uniform vibration level across the entire structure.

Compressors also are noisy engines because they are not well balanced and they are typically double suspended, that means they have their own suspension on top and then below you have an intermediate raft which is also suspended. We have made also an investigation and the beauty of this system is that we can demonstrate on our research vessel that using the active isolators you can reduce the vibration for sure but you can also reduce by roughly the same amount the acoustic emission in far field. And that’s I think for military application it's quite important to demonstrate that.

A project that we have also developed for the DCNS is double stage or what we call double stage active suspension for very highly demanding applications so the design is based on—you see these large isolators, it's shock isolators and then you have a welded structure where we have introduced the activators in the sensors; this welded structure itself suspended and it makes like a double stage suspension, but the intermediate mass will be controlled. This is the factory where we have some test rigs where we have installed also shakers on top of this round structure which is supposed to mimic the engine, so we have records of the real engine and we play those records to generate the vibration field. And here is a look at the results—the green spectrum is the vibration that is introduced on top of the isolators, the red spectrum is the vibration measured on the floor level of the factory without control and the blue is the results once activated. For this experimental investigation we have configured the control unit to handle 16 orders which is fairly large I would say, but it's not a limit for the hardware itself, and you can see here what this direction, the success we get up to 30 db average reduction in the control frequency range. The same results for the Y axis and the same results for the Z axis. On this ship we have conducted several investigations on gen set application. This is a ship which has an electric propulsion and therefore it has also gen sets. These gen sets are delivered, well the engine is delivered by MTU, it's a 12V 4,000 series. And you can see here the double isolation with this intermediate raft, the green welded structure. Also the basic idea here was to implement actuators and sensors on this intermediate raft and to make sure on the foundation that we could reduce the levels quite significantly. So here is a picture of the installation on one side, the system was configured to control several engine orders; you can see 1.5 up to 4.5. we had roughly no knowledge as to how this raft structure would vibrate so we just glued actuators and sensors and I would say it was quite good from the very first experiment. So basically some results performance—you can see here on the left upper chart the levels measured by the different sensors, the red circles are levels on the structure without control and the blue with control. We got always roughly between 20-30 db reduction and we could also measure that even on a ship's skin very far away from the gen set we can measure up to 9db reduction without any system optimisation or preliminary analysis. So it's quite interesting. Propeller induced vibration is something very interesting where you have limited options; a lot of people are doing propeller optimisation but there is little room for how to control these pressure pulses generated by the propellers so you usually have to live with it. One way is to introduce like bubbles between the hull structure and the propeller but up to now we could only demonstrate up to 4-6 db reduction, what we suggest is to use new actuators that would deliver quite large force levels in the range of 4-5 kilo newtons while still being relatively compact and to use those actuators that would be implemented on the hull structure above the propeller unit to control those vibrations. And this is an experiment that will be carried out in the next months, so perhaps in the next session or at least next year we can talk a little bit about propeller control.

So some facts as conclusions. For me active vibration control is very interesting because it can give you a high performance, it's quite flexible and versatile and can be used for new build, upgrade or retrofit and it's very interesting when we are talking about again weight and space requirements. Thank you so much for your attention.

Martin

Mathieu, thank you. OK some light please and we'll have 10 minutes of questions and extend by about 10 minutes. Hands please.

Tork

The Hutchinson system—have you applied that to a yacht project as yet?

Mathieu

Yes, we have already developed a system two years ago, it was really the first one and we are in discussion with several yards to implement the system on new projects now.

Tork

Are you allowed to say which yachts?

Mathieu

I'm not sure!

Mike Hein Captain, Mea Culpa

If you've already done MTU 12V 4,000 engines, is the information that you've done on your past projects available for myself to take a look at?

Mathieu

If I understand right, the question is, is it only dedicated to this kind of engine?

Mike

No no. Specifically those engines that you've done, you've already shown 12V 4,000 engines where you've taken out the old mounts and put in your active system.

Mathieu

We jumped into a project with MTU because there was a high requirement from the yacht manufacturers and sometimes life is good because we were just in the right place at the right moment. And fortunately we could offer the yards this solution, because MTU was trying to develop passive solution but with compromises that were difficult to handle. So the active solution was a good solution because you can still have a relatively rigid passive mounting system while having a superb isolation efficiency.

Jim Ruffolo Burger Boat Company

So that we can evaluate the improvements that were made with your active system, Mathieu, on the passive system that was used, was that the best systems that are out there or was that part of your system ? just trying to compare the improvements that were made with your active system.

Mathieu

We delivered a system with isolators and some systems does not require any isolators that means it can be only actuators, sensors and control unit. The benefit of using this system is that again, usually the shipbuilder likes to have an engine with suspension tuned to a given frequency range, that means not to have extremely large displacement under rough sea conditions, so you have integrated that in your design I would say the passive part of the system is fixed. But then if you want to have very good isolation efficiency I think in my opinion the only way is then to introduce the active part of the system, that means you have to introduce the system right from the beginning of the project.

Jim

OK, again, just for clarification, are you saying that the passive system is one that the shipyard would typically use, or is that part of your system, the passive part of your complete system ?

Mathieu

No, typically the shipyard will ask us to deliver the whole system including the passive isolators as part of our scope of supply.

Christof Weissenborn Germanischer Lloyd

A question to the first paper given. What we see here is a MDF, multi degree of freedom input output system, which includes numerical electronic components. The question is related to reliability. What is the fallback strategy or the emergency operation mode of these gen set isolation?

Reza

I'm not sure if I got the question quite right. Could you repeat it please?

Martin

What's the fall back position if anything goes wrong?

Reza

The reliability of air mounts nowadays at least are very much proven. If you look at all the trucks on the road, just about all of them nowadays have air mounts in them, so if it can handle the hardship of the road in the Winters of north Europe it would be a very reliable device. Now in terms of in case something goes wrong what would be the fall back, you can always put hard stops around the machine just in case let's say somebody kicks one of these mounts and tears it off then it doesn’t quite fall, it goes on maybe about ½" and sits on some sort of a rubber stop. I don’t know if I answered the question?

Christof

Yes it does. Another question—up to which frequency this system is working with regard to the dynamic stiffening you said you can pump it up very quickly. Which is the easier—the rise time of the pressure or of the erecting force?

Reza

Well, we don’t quite go ahead and pump up the system. We dynamically change the amount of air, I should say a little bit of air going in and out of the mount when we want to go ahead and change the stiffness of it. So you can go through about 200-300% change in the stiffness in the matter of a few milliseconds.

Martin

Are you happy with that? I have one question which is unfair, I think.

Tork

A question for you both, and then a question for the Deicon system. Generally it would appear to me that although ideally put in at the new build stage both systems can actually be retrofitted ?

Reza

Correct. In the applications we have done they were both retrofits. The owner was not happy with what the yard put in place and it was a year old yacht built by a very reputable yacht builder.

Mathieu

Yes, I would just mention the potential that we can do retrofit, or what I call an upgrade, which means you have perhaps a gen set which has even isolation system and we can even not have to remove anything from the existing system, just plug actuators and sensors and then improve on the situation. And that’s very interesting because usually most of the shipyards or owners or captains who would like to improve on the existing hardware have concerns about having to remove the engines or the gen sets.

Tork

And my question on the Deicon system—I know your system, we wrote about it before. It now sounds, am I correct in thinking, that the system that I saw and the system that you now have, today's system is fully continuously active, is that correct? The system that I saw had three separate stages but now the system is continuously active?

Reza

Yes, the system is always under the supervision and control of the computer. So if the computer monitors the accelerometers, situated properly and realises that it's more than it's supposed to be at a certain frequency, it automatically goes ahead and changes the stiffness increases or decreases it. And damping also at the same time, and also lateral engagement and disengagement.

Martin

OK. My little question. I want a candid response. What do you think of each other's systems? Honestly. Because your CVs say you're both brilliant people in engineering, so what do you think of the Hutchinson, and what do you think of the Deicon?

Reza

Let me go first. You know, there is no silver bullet when it comes to noise and vibration. Each system has pros and cons and we try to promote our system specifically for diesel generators and we believe for the cost, complexity, and all of the headaches that are involved in retrofitting one or putting one new in place, it's an attractive choice for diesel generators.

Mathieu

Yes. Regarding the cost of a propulsion system which can be fairly high, I would say our goal is of course not to over engineer the system, which means we want the system to be just the necessary system and the cost of our system has to, in the future, remain within a limited percentage of the overall propulsion system, that means when you integrate the active system in the propulsion supply it's only a few percent more over the cost. And we are talking about costs for today lower rate production. Which means if the system could be generalised, standardised, which because today it's more or less a custom system each time. So if we can go through somehow standardisation then I think costs will drop dramatically and make things more affordable.

Martin

In terms of the superconductor and diesel electric, what are your views on that? Does that make your life easier?

Mathieu

Certainly more costly for us.

Reza

I guess it would make it more attractive what we are offering because now we have a lot more diesel generators and we are back into diesel generator isolation, rather than main propulsion engine isolation.

Martin

Alright, any more comments from the floor before we wrap for a coffee break of ½hr. Thank you very much at the back? Last question.

[From the floor]

The controlling system. How's that going to survive in the aggressive working environment that there's going to be in an engine room?

Reza

Well in our system basically the controller is just a small micro controller, it's a very small low cost device, $50 is the cost of the micro controller itself. Now the programme you put in it is a different story. So it's small, it can be tucked away in a control cabinet and there are a few pneumatic valves, and pneumatic valves have proven to be very robust and very reliable and very low cost. So I guess it is a very reliable system.

Mathieu

Well we have also designed a system that it can survive in the engine room quite a long time, because we put a lot of emphasis to take into account temperature, damp heat, salt spray issues and things like that. So the electronics, the power amplifiers, power supplies, actuators, everything has been somehow protected against these kinds of risks and up to now the system that has been delivered 2 years ago is still operating fine, so I hope that it will continue to work at least a few years more.

Martin

OK. Does that answer your question? Thank you very much gentlemen. We'll see you all back here in 30 minutes, 16.40. Thank you.