BRITISH ACOUSTICAL SOCIETY

71SA5

SESSION MEETING,

5th - 9th April.

HOVERCRAFT NOISE AND VIBRATION

by

E. J. Lovesey C.Eng.

1. INTRODUCTION

Passengers and crew comfort are largely dependent upon body vibration, noise, seating layout and space, temperature, ventilation and vision. In order to overcome the effects of some of these quantities, different engineering techniques have been employed in the design of each individual hovercraft. This has resulted in a wide variety of hovercraft configurations ranging from entirely amphibious airscrew driven craft to non-amphibious water screw propelled sidewall hovercraft[1].

In general, airscrew driven craft produce more external noise but have the advantage that they are completely amphibious and faster than other forms of hovercraft. hydrofoils or displacement vessels.

Fan driven hovercraft are quieter but slightly slower and at present are comprised of small experimental craft.

Water screw driven hovercraft are also usually quieter than those propelled by airscrews. However existing craft of this configuration are slower and either non-amphibious or only partially amphibious. Non or partially amphibious craft are less manoeuverable and more susceptible to damage by floating debris but tend to be cheaper to operate and simpler to control than other forms of hovercraft.

2. HOVERCRAFT NOISE

Unlike commercial aircraft, the external noise level has decreased as hovercraft have been developed and have increased in size and power[2].

TABLE 1
MAXIMUM NOISE LEVELS OF HOVERCRAFT AT A DISTANCE OF 500 FEET

Hovercraft	AV Weight lb	Installed Power SHP	Year	Noise Level dBA
SRN2	61,000	3,200	1962	94
SRN3	84,000	3,540	1962	94
SRN5	15,000	900	1964	95
SRN4	400,000	13,600	1968	78
VT1	150,000	3,700	1969	69

Hovercraft tend to be less noisy than aircraft of comparable installed power to those outside of the craft, while inside the level is approximately the same as that in a commercial jet aircraft and much less than that in most helicopters.

Hovercraft noise emanates from a number of sources of which the most important are the propeller, engine intake and exhaust, fan intake, cushion efflux and transmission noise[3].

2.1 EXTERNAL NOISE

Propeller noise is generally the worst from craft with airscrew propulsion. The noise from propellers can be divided into rotational noise and vortex noise. Rotational noise occurs at discrete frequencies corresponding to propeller rotation speed times the number of blades and harmonics of this frequency. The noise is dominant at high tip speeds approaching the speed of sound. At low speeds the vortex noise predominates. This noise is thought to originate from pressure fluctuations around the blades.

Early hovercraft made use of the only propellers which were readily available. These were originally designed for use by aircraft flying at 400 mph and were noisy and inefficient at low hovercraft operating speeds. By redesigning the propellers for low speed use and by reducing the tip speed from 1000 to 800 ft/sec an impressive reduction in noise level has been achieved together with an increase in propulsive efficiency. There is, however, a limit to which the tip speed can be reduced to give an appreciably improvement, since below about $M = 0.7$ the greater proportion is composed of vortex noise. The maximum noise tends to be emitted more or less radially outwards (105° to craft fore and aft axis).

The low external noise level of the SRN4 is largely due to the careful design of the four 19 feet diameter propellers and also to the knit-mesh filters and their housings at the engine air intakes. With early gas turbine powered craft the noise from the engine compressor was as great a problem as the propeller noise. The quickest solution for this is to use splitters, which have been used very effectively on fast patrol boats. However, the installation is bulky and cannot easily be fitted retrospectively to a craft, but it has been designed into the SRN4 at an early stage with the resulting improvement in noise level.

Fan noise generation is similar to propeller noise but the number of blades are greater and the tip speeds are lower (300ft/sec). Fan noise is usually constrained by ducts and the plenum chamber.

Cushion efflex and exhaust velocities are low though the noise may be a noisance to passengers in nearby terminal buildings during low speed manoeuvring over the hoverpad. This noise is of even less importance when the craft is travelling at speed.

Much of the external noise that reaches a maximum during manoeuvring at the terminal area is due to propeller pitch changes. These pitch changes may produce high frequency peaks of 100dB but these last for a few seconds only. During idling the noise at the terminal will die away to 75-85dBA.

In fact, the noise from SRN2 and SRN5 hovercraft arriving at a terminal 500 feet away have been compared favourably with the noise at a point 60 feet away from a busy main road.

In a busy urban area, the presence of a hovercraft terminal will do little to produce any appreciable increase in the overall noise level. Unfortunately several existing terminals have been sited on the coast near to residential areas. These have produced a number of complaints from people who have retired to these areas for peace and quiet.

2.2 INTERNAL NOISE

Much of the internal noise in hovercraft results from inadequate sound proofing and is due to transmission noise, engine noise and fan noise. Once a hovercraft has been designed and constructed it is difficult to add sound proofing retrospectively. Apart from cost, it usually adds an unacceptable weight penalty and is often far from effective.

On early commercial hovercraft the cabin noise levels were as high as 90 dBA, but were tolerable since the journey time was of only a few minutes duration. Current hovercraft noise levels are similar to those found in commercial jet aircraft.

3. MOTION AND VIBRATION

Surface transport ride comfort can be regarded as a function of vehicle speed, surface profile and vehicle suspension.

In the case of a motor vehicle, the suspension system (including the occupants' seats) has a combined stroke of a few inches. Consequently the surface over which it travels has to be tailored to the vehicle. This has resulted in the construction of relatively smooth but expensive tarmac'ed roads which enable speeds of up to 70 mph to be reached with safety.

The marine environment is at present beyond the simple control of man. Thus the amphibious hovercraft suspension system has been designed with a stroke of feet in order to travel at speed over the short wavelength high amplitude irregularities in the form of waves.

Wavelengths shorter than half of the cushion length are, in effect, damped out by the cusion suspension system and hardly affect the hovercraft's motion.

Wavelengths equal to, or slightly greater than the cushion length produce maximum pitch forcing and craft motion depends upon the cushion stiffness and damping.

When wavelengths are many times the cusion length the craft will tend to follow the water surface and produce high amplitude low frequency oscillations.

Generally, for good ride properties the cushion should be soft with low stiffness and damping.

Although hovercraft may produce very low (circa ½Hz) frequency, high amplitude motions in extreme conditions, most of the motions are of a higher frequency (4.20Hz) due to short choppy seas and the suspension characteristics. Unlike helicopters and hydrofoils, this vibration is confined almost exclusively to the vertical or heave axis. There is little low frequency horizontal vibration in the sway or shunt directions due to the typical rectangular shape of the hovercraft being stiffest laterally and longitudinally.

During his evolution, man has always been exposed to heave vibration when walking, running, jumping etc, but has rarely been subject to motions in other axes. Consequently it is not surprising that he can tolerate heave vibration better than he can tolerate sway or shunt vibrations. Thus, one advantage of the hovercraft is that it does not produce its own vibrating environment in these 2 axes but essentially limits vibrations to the heave direction, which is the most acceptable to man.

However there will always be occasions when a hovercraft passenger is given a rough ride but it will probably be far smoother than the ride produced by an alternative form of surface transport over a similar sea. For example vibrations were measured at the floor of a small hovercraft travelling at 15kt and compared with the records from a 28ft launch at 28kt over a smooth sea (waveheight 1-1½ feet). The half peak to peak g levels and frequencies are given in Table 2.

TABLE 2

Craft	Speed	Heave		Sway		Shunt	
	Knots	f	g	f	g	f	g
Hovercraft	45	4.7	.14	12.5	.05	4.7	.06
Launch	28	1.2	.6	1.2	.15	1.2	.10

It can be seen that even at an appreciably greater speed, the hovercraft produces a vibration level of approximately one third that of the launch.

As hovercraft increase in size and more is learnt about the characteristics and design of cushion systems the ride will steadily improve. In the meantime, the ride comfort can be improved by the use of rearward facing seats for the crew. A rearward facing seat is a useful way of restraining a passenger from pitching forward when subjected to moderate decelerations caused by hitting heavy swell, without having to resort to wearing a seat harness.

The sprung anti vibration seat uses a spring damper system which effectively isolates the user from frequencies around 5Hz which excite the vertical body resonance.

CONCLUSIONS

Since hovercraft were introduced just 12 years ago, internal and external noise levels have been steadily reduced.

Hovercraft now operate in rough sea conditions at speeds far in excess of those achievable by most other forms of transport at relatively low vibration levels.

Further refinements in noise control and suspension design will improve ride comfort and strengthen the position of the hovercraft as a link in the high speed marine transport field.

REFERENCES

1. E. J. Lovesey — The Hovercraft Environment Applied Ergonomics. June 1970, Volume 1 No. 3, Pages 134-139.

2. I. Cross and C. O'Flaherty — Introduction to Hoverports. Hovering Craft and Hydrofoil. July 1970, Volume 9, No. 10, Pages 40-47.

3. E. J. Richards and I. J. Sharland — Hovercraft Noise and its Suppression. Journal of the Royal Aeronautical Society. June 1965, Volume 69, No. 654, Pages 387-398.