THE DYNAMIC BEHAVIOUR OF THE FLOATING SURVIVOR IN SEA WAVES AND ITS EFFECTS ON AIRWAY PROTECTION

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INTRODUCTION

Lifejackets are worn to provide protection from drowning. Their performance is specified in terms of mouth freeboard, flotation angle, self-righting, and stability in tests that are usually conducted in calm water, the assumption being that this performance is related to the protection provided in waves. Dynamic tests are difficult to perform. Real sea waves do not provide a reliably reproducible environment and the danger of drowning for the human subject wearing a poorly performing lifejacket is very real! Limited wave simulation is possible in large tanks, but these are expensive and do not abolish the risk of drowning for the subject In any case, the measure of the degree of protection provided will be very subjective and influenced by the subject's reaction to the wave insult. Marine manikins have been developed that remove some of these difficulties and these can be fitted with devices to measure the protection provided by immersion protective clothing assemblies. This paper describes experiments which demonstrate how h e protection provided by a lifejacket as measured by a simple assessment of static freeboard may not reflect the performance in waves. The method was extended to demonstrate how well a marine manikin simulated the flotation characteristics of relaxed human subjects. Finally, a device to measure the protection provided by a lifejacket was calibrated using a breathing dummy head.

METHOD

Two immersion-suited subjects (nude weight 67kg & 110kg) and a nude water-filled fabric manikin (wt 106kg) were subjected, for a range of flotation angles of 0-90^{o}, to vertical impulsive displacements in an immersion pool (6x2.5x3m) while wearing regular *military* lifejackets. Their subsequent transient motion was recorded digitally at a 32Hz frame rate using an image array camera system together with helmet-borne LED markers arranged to detect both rotational and translatory displacements. The static buoyancy/immersion characteristic of the lifejacket was also determined Similar impulse and static measurements were made on 4 subjects (nude weights 63, 75, 78, 85kg) and two commercial marine manikins (RAMM1, RAMM2; RGIT OSC, Aberdeen, UK) (nude weight 72kg) to determine whether the manikin dynamic behaviour adequately simulates that of relaxed humans. Tests were conducted with subjects and manikins both nude and attired in lifejacket/protective clothing combinations commonly used by UK offshore operators.

Motion recordings, employing instrumentation similar to that above, were made of 3 human subjects and RAMM2 floating in simulated sea waves of fetch 7km (576m^2 wave tank), in accordance with h e Joint North Sea Wave Project (JONWSAP) power spectrum (1). Data from a 4 LED helmet-mounted array were collected as the untethered subjects, wearing various lifejacket/immersion suit combinations, floated through the camera view field (time window = 30s).

In a parallel study the performance of a mouth-mounted splash detector system, which has been used with RAMM to assess the protection capabilities of immersion/flotation clothing (2), was compared with that of an RAF IAM system of different design (3). Both devices were mounted on an artificially ventilated dummy head which accurately modelled the human upper airways and were immersed in simulated waves of varying severity. Water volumes inhaled by the dummy during 5 minute intervals were recorded, together with response frequency and duration of the *two* splash detectors.

RESULTS

Post-impulse motion data from subjects and fabric manikin were analysed to distinguish the vertical linear (z) and rotational components. Rotation was generally less than 14^{o} and contributed little to vertical motion of the mouth. Using a second order model, exponentially damped sine waves were fitted to the invariably oscillatory z component data and mean values for damping ratio and natural frequency were derived. Damping ratios and natural frequencies were in the ranges 0.054-0.230 and 0.49-0.8Hz, respectively. The manikin exhibited the lowest damping, perhaps due to absence of clothing, while resonant frequeocy increased with flotation angle (possibly due to increased body flexion at a near horizontal attitude). Idealised frequency response plots were produced in order to predict the effect on mouth freeboard of motion in sea waves. These showed peak magnification factors ranging from 2.5 to 9.5, depending on damping. An expression was derived relating minimum freeboard to avoid mouth immersion with steady state frequency response parameters, and it was shown that there was sufficient energy in typical sea waves around the measured natural frequencies to cause transient mouth immersion when the static freeboard is 0.11m.

A similar analysis of the RAMM/human subject comparison data showed that for both humans and RAMM manikins the natural frequency and damping ratio were greater ($p<0.05$) for the dressed condition, consistent with increased stiffness and drag. For the dressed condition, human natural frequencies were proportional to the reciprocal of the square root of the subject's mass ($p<0.01$), and the natural frequencies of the manikins were within the range of the human values. For the undressed case, the manikins' natural frequencies were slightly lower than those of the humans. Small differences io damping ratio for humans and manikins were also determined for both dressed and undressed conditions.

For the simulated sea wave trial analysis, power spectral densities were estimated from the z data. Attention was concentrated on 20 frequencies between 0.31Hz and 1.5Hz since most of the power in the responses was concentrated in this band, as was that of the JONSWAP waves. Small but significant differences between the power in human subject and RAMM2 motions were determined at frequencies near 1.0Hz. Differences in response power of both manikin and humans when wearing 3 lifejacket/immersion suit combinations were clearly shown in the range 0.56Hz to 0.81Hz.

Analysis of splash detector signals showed that for the IAM device (4 probes spanning the mouth) the best correlate with inhaled water volume up to 500ml was the percentage duration of a logical-AND sensor signal combmation (R^2=0.985). For the RAMM system (2 bilateral probes) the best correlation obtained from mean event rate (R^2=0.981). This difference in performance is in part attributable to the greater responsivity of the IAM device. The results indicate that on average 41 splashes or a total splash duration of 1.5s will cause inhalation of 200ml of water, which can cause drowning (4).

DISCUSSION

Despite the limitations of the simple linear model (eg, uon-rigidity and nonlinear buoyancy-displacement characteristics of the floating bodies), the results suggest that the impulse method is useful in predicting real wave behaviour, which is borne out by the simulated wave measurements, since both techniques showed small differences between human and manikin responses. The initial study provides evidence that a more horizontal flotation attitude improves the dynamic freeboard, io that damping and resonant frequency are increased; other methods of achieving this end may be investigated with the impulse test.

The RAMM splash detector investigation showed that it provided a reliable prediction of airway protection and agreed well with the performance of an independently designed system.

CONCLUSIONS

Current lifejacket design, while addressing such aspects as wearability, stability, self-righting, spray protection and freeboard, should also take account of the dynamic behaviour of the wearer in waves, which may be modified. for instance, by other clothing. Impulse testing in a small immersion pool together with splash measurements in real sea waves, using a marine manikin as the test vehicle, affords a safe technique of assessing these additional performance factors important for airway protection in waves.

REFERENCES

1. Carter, D. J. T., Estimation of Wave Spectra from Wave Height and Period. Institute of Oceanographic Sciences Report No 135 (Unpublished Manuscript), 1986.

2. RGIT OSC, In-Water Performance Assessment of Lifejacket and Immersion Suit Combinations. Department of Energy Report OTI 88 538, HMSO, London, 1988.

3. Higenbottam, C. & Berry, A., Assessment of a Method of Predicting Inhaled Water Volumes in Waves. RAF IAM Report No 663, 1989.

4. Halmagyi, D. E J. & Colebatcb, H. J. H., Ventilation and Circulation after Fluid Aspiration. J App Physiol 16(1), 35-40, 1961.