

Criteria for Designing Noise and Vibration Comfort of Passengers on Board of Ships

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Abstract

The issue of shipboard habitability related to vibrations has been governed for years by the ISO standard 6954:1984, a very popular point of reference for shipbuilders and shipowners. In 2000, the ISO 6954 standard has been revised. This new standard promotes a new approach that should better reflect the human perception of vibration. On the other hand, it leads not only to stricter limits, but also to an additional challenge on theoretical vibration level prediction, which will increase uncertainties in comfort design. While the old ISO standard has proven to be very effective, the new one is still a question mark.

In latest years a further revision process has begun, with the aim of drawing up a more reliable standard. The future standard ISO 20283-5 has not been finalised yet (see ISSC 2009 Committee II.2). In the meantime, the approach of the old ISO standard should be kept as the only sound reference by shipbuilders and shipowners for signing new contracts.

The point of view of authors is that a new ISO standard may be enforced only after a definitive study will have clarified how distribution and amplitude of excitation frequencies affect the passengers comfort on board of ships. At the same time, it is well known that the old ISO standard is starting to show its age. Thus, only a part of the framework of the 1984 version needs to be modified – as, for instance, the controversial concept of the maximum repetitive peak value.

In what follows, the new ISO 6954 rule is examined in order to substantiate the hesitation of shipbuilders and shipowners to use the approach proposed by this new version. Finally, based on comparison between the two present ISO approaches, authors discuss the open question of the structure to give to the future ISO 20283-5.

Introduction

The issue of comfort on board of cruise ships has become of paramount importance in the last years, since the judgment expressed by passengers on their stay aboard is based above all on the quality of the well-being perceived in the various spaces of the accommodation decks.

In general, the choice made by a potential passenger of cruise ship is influenced by a variety of factors, such as itineraries, fares, on board facilities, degrees of luxury, each of them considered on the basis of the personal preferences. However, the most important factor that conditions the choice, whatever it will be, is the confidence that a sufficient personal comfort will be assured on board cruise ship.

Passengers determine their acceptance of a cruise ship on the basis of objective and subjective considerations relating essentially on their perception of comfort and safety.

Among all the different factors relating to comfort, noise and vibrations are undoubtedly the main topics, becoming a crucial issue in a design procedure oriented to the satisfaction of the passenger's expectations.

Thus, providing low levels of noise and vibrations is decisive in maximizing the comfort on board, and shipowners give great importance and define extremely strict limits with regard to this issue, even if the problem of defining the acceptable comfort level on board represents a difficult task. Comfort has become an important contractual item, supported by heavy penalties if not fully complied before the ship delivery.

In this situation, designers get involved in accurate predictions of noise and vibrations levels. Design process can be only based on their experience gained by the cooperation with shipowners, which in turn test the quality of cruise ships on the passenger's feedback.

As a matter of fact, experiments and simulations can not be effective for testing a comfort level, since, during a test, people will be certainly not in the same psychological state as they are on board during a cruise. Consequently, the comfort oriented design need to be based on the verification of the real comfort perceived by passengers. The feedback got from passengers is usually expressed in terms of notes presented to shipowner.

For assessing an acceptable comfort level on board, shipowners and designers can also make reference to rules and standards, that, however, hardly provide an effective guidance, since they do not consider nor the interaction among all the possible sources of disturbance, neither the subjectiveness of the passengers response to the different stimuli influencing their sensation of comfort.

On the other hand, with the purpose to better quantify the comfort perceived by passengers, and hence the comfort quality offered on board, rules limit of levels of stationary noise and vibration and indexes characterizing the non-stationary noise are under continuous evolution. Evolution of the rules is certainly a quite long and difficult process that should also take advantage from best shipbuilder practice with the aim of providing practical and reliable tools, able to give to designers a better understanding of the design principles.

Nowadays, new rules and standards on comfort quality on board ships are under discussion with the purpose of enhancing the comfort offered on board and, at the same time, to meet the expectations of the maritime industry for guidelines consistent with the ships environment.

A consolidated design philosophy

The rules of the International Organization for Standardization and the International Maritime Organization have been during the years a sound standard of reference for both shipyards and shipowners concerning the vibration and noise limits on the ships.

Today, in the shipbuilding field, the comfort oriented design concerning noise and vibration is governed by two single rules:

- the ISO Rule 6954:1984 “Mechanical vibration and shock, Guidelines for the overall evaluation of vibration in merchant ships” concerning hull vibration, originally proposed to be applied to crew accommodations only, but at present applied mainly for passengers and crew accommodations areas;
- the IMO Rule A468(XII):1981 “Code on noise levels on board ships” concerning the air noise in the various types of spaces on board, including the working areas (for instance the engine rooms), and proposed to securing an acceptable comfort level to the crew.

On these bases both shipyards and shipowners for many years took advantage of the common experience made in applying the aforementioned standards and by assimilating in the design philosophy the approach proposed by the rules. The know-how of shipyards has in time undergone a constant improvement, allowing to meet the challenging requests for a higher quality comfort on board of cruise ships.

As a matter of fact, limit values set by the foregoing rules are a benchmark in the procedure for the determination of the vibration and noise levels on board the ships. In such respect, it is worth noting that, while some years ago the shipowner specifications used to establish as limits precisely the rule limits (in other words the shipowner higher limit was equal to the regulation lower limit), now there is the tendency to lower the limit values aiming at ever higher comfort characteristics.

However, it is to be remarked that shipyards and shipowners usually adopt the standard based on the “peak values approach” (that given in the ISO 6954:1984) as reference, reducing their limits and differentiating them between areas devoted to passengers and crew.

The lower limit of the range of acceptability mentioned in the old ISO Rule has always been considered the maximum limit tolerable. It is equal to 4 mm/s of peak value when, in the range of medium and high frequencies, the crest factor is not taken into account ($C_F = 1$). As above mentioned, such limit value represents the starting point for the determination of an ever increasing level of comfort for the accommodation spaces for passengers and crew.

In the meantime, shipyards and shipowners have been assisted by the Classification Societies, that provided specific advice on the subject. Det Norske Veritas, first among them, have studied and set guidelines for the evaluation of the comfort on board, supplying directions on the vibrations and noise limit levels. In particular, different levels of comfort quality have been set, differentiating the corresponding limit levels in accordance with the ships type.

The ISO standard impasse

ISO standard 6954:1984 outlines a straightforward procedure for the measurement and evaluation of vibrations with regard to shipboard habitability. This standard is regarded as a milestone for a reliable assessment of comfort on board of ships. In the last years the theoretical and practical approach given in the 1984 version has been abruptly changed by the issuing of the final draft of the 2000 version, whose framework is highly questionable, at least from the point of view of shipbuilders (De Lorenzo & Biot, 2006). On the other hand, an enhancement of the old 1984 standard could not be postponed, since such a version has been accepted for years despite lack of complete satisfaction. As matters stand, it is taken for granted that in order to look at how to overcome the present impasse a review process of new ISO 6954 standard cannot be avoided.

In this frame, ISO technical committees have started to work on a reviewed standard that should be included as part 5 in the new standard ISO 20283 covering the whole range of

vibration on ships. The essential requirements of the new approach should be effective in estimating the real level of comfort and, at the same time, in being of practical use for shipyards and shipowners. The main issue is that it does not exist an updated and in-depth study regarding the effects of vibrations on passengers comfort on board of ships. In effect, the specific ISO technical committee is encouraging experts to collect all available data for improvement of ISO 6954:2000.

Handling the real comfort

The main feature of ISO 6954:1984 is that, for the purpose of assessment, each excitation frequency of a vibration spectrum is considered to give a separate contribute in terms of human perception of comfort. The admissible vibration level for each excitation frequency is expressed as maximum 0-peak value (see Fig. 1).

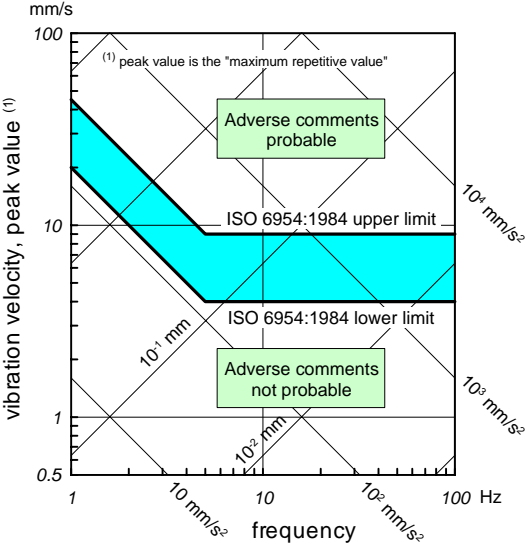


Figure 1: The ISO 6954:1984 vibration limits.

The approach was validated by a lot of measurements made on board of ships during several years and after statistical analysis of the behaviour of the people on board. The statement “Adverse comments not probable” which marks the area below the lower limit curve in diagram of Fig. 1 is very effective in defining a basic level of comfort. Higher comfort levels may be set by lowering the limit curve. Moreover, even if periodic excitation forces are subjected to a certain degree of variation, the regulation approach allows routine calculation predictions and quick and easy experimental measurements. This is why the old ISO standard gained general acceptance for the evaluation of shipboard vibrations with regard to human exposure.

Clearly, limits to vibrations in the accommodation area of a ship should guarantee an optimal comfort level. Unfortunately, there is lack of information about the human perception of vibrations, at least as far as shipboard habitability is concerned. Exhaustive research in close cooperation between ship vibration experts and psychologists should be carried out. Up to that time, the best rule is to act in accordance with the experience gained by shipyard and owners. Other opinions have a very relative value.

To prove the strength of the above statement, results of an investigation carried out by the authors (Biot & De Lorenzo, 2007a) made on the notes presented by passengers about noise and vibrations disturbances perceived in the cabins of a cruise ship during a certain number of voyages are here summed up. The investigation was performed with a practical approach which allows the measurement and monitoring of the real comfort on board of cruise ships.

All the sources of noise and vibration on board have been considered, and the subjective impressions of passengers have been taken into account. It is worth stressing that noise and vibrations disturbances are handled together because of their nature; being dynamic factors, they are considered the comfort attributes with the greatest influence on the perception of well-being in people on board and, within the comfort design, are called “active parameters”.

The applied procedure consists in gathering, processing, and analyzing passengers judgements in order to correlate the comfort perceived by passengers (the real comfort) and the objective quality of the offered comfort, measurable by means of physical parameters. In the case here presented, a number of judgements has been collected and classified on the basis of the different types of sources of disturbance (Fig. 2).

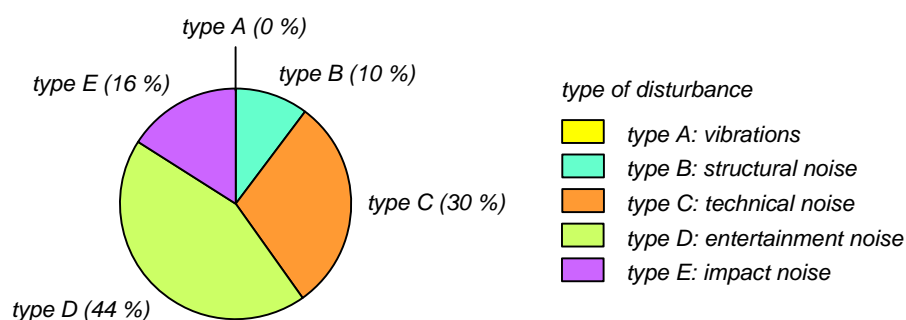


Figure 2: Different influence of the sources of disturbance.

Since analyzed data refer to a modern cruise ship involved in routine voyages, the results here presented are significative of the level of comfort on board of cruise ships of the latest generation. For what concern vibration annoyance, the main conclusion of the analysis is that no claims have been registered. That is a prove of the ability of designers in dealing with the

vibration phenomena, even if they set comfort design just on velocity levels in mm/s peak at any single frequency.

Old versus new ISO standard

The new ISO approach based on a “integrated weighted” overall level expressed in mm/s RMS is apparently valid as it considers the human perception of vibration as a whole. On the other hand, a global value which can synthesize all the vibration effects on human perception is not completely convincing when the energy of the vibration spectrum is mostly concentrated on a narrow band, since a vibration spectrum is not perceived by the body as a whole, but by any part of the body as a single part. The analogy with the concept of dB(A) in the noise field is very attractive, but to argue from analogy may lead to wrong conclusions.

Another question is the starting point of ISO 6954:2000, which in our opinion – an opinion shared by many experts, is not strictly correct. In effect, the new standard is based on the ISO 2631-2 standard, where human exposure to whole-body vibration is accounted, with the aim of limiting the annoyance and comfort effects on occupants of buildings. The “base curves” of that guideline (which in substance reflects the same human sensitivity of the old 6954 standard) represents magnitudes of equal human response with respect to comfort perception. Depending upon specific circumstances, the base curve should be properly raised.

The new standard was introduced without having been seriously substantiated by measurements of shipboard vibration and till now the situation has not changed very much. However, the sensitivity curve has not been raised by a proper multiplying factor and it has been applied to in shipboard comfort just hoping that what has proven to be valid in other fields (i.e., in buildings) would also be valid on board of ships. Moreover, the issue of long-term familiarization on board of ships has not been considered.

Finally, the method defined in the new ISO approach does not appear effective, since its very complicated framework leads to increased uncertainties in vibration prediction and real comfort assessment.

Many comparisons have been made between the outcomes resulting from the implementation of the two procedures outlined in the old and in the new ISO standard (Carlton & Vlašić, 2005; Biot & De Lorenzo, 2007b; Savreux *and al.*, 2007). As it was widely demonstrated without any doubt, accordance between the results of the two approaches is not always clear, depending on the type of the signal: this means that something is not correct.

As a clarifying example of how the new ISO standard is inappropriate to identify critical conditions, some measures acquired on recent passenger ships are reported here (Biot & De Lorenzo, 2007b). Measurements have been made, in accordance with the standard practice, during the trial test, i.e. at 100% of the maximum continuous rating (MCR) in a moderate sea state. Computations of the time records have been made by referring to the procedures defined in the old ISO 6954 standard and in its new version.

The results of the two procedures have been compared in terms of the check ratio c , defined as the ratio between the measurement outcomes elaborated according to the two ISO standards (reference values) and the relevant limit values. A check ratio $c = 1$ means that a limit habitability condition (in relation to vibrations and according to one of the two standards) has been reached in the location where the time record has been taken. Based on the firm belief of the authors on the effectiveness of the peak value approach in evaluating the real level of comfort on board of ships, an equivalent crest factor equal to one has been taken. The measurements carried out on different ships were about some hundreds. For almost all the surveyed locations, satisfactory results ($c < 1$) have been obtained by enforcing both the standards. Just for about ten locations the only check ratio calculated according to the new standard was found greater than one, while the check based on the old ISO standard was positive. The reason of the disagreement may be explained by analysing the vibration spectra: in all cases, inconsistency may be related to propeller cavitation and to ship motions (i.e., peak at very low frequencies).

One of the two approaches fails in evaluating the habitability. Based on the common experience that the old ISO standard may be considered fully satisfactory since it is extremely effective in emphasizing critical areas, one may argue that the new ISO standard, supplying indications that diverge from those of the old one, does not offer the same requirements of reliability. In conclusion, the new layout may risk to overestimate the vibration effects on the real comfort and to interpret levels not noticeable by passengers as critical vibration. As an example, Fig. 3 shows the vibrations measured on board of a cruise ship as elaborated according to the old and the new ISO standard. The assessment of habitability made on the base of the 1984 version gives a vibration level equal to 17% of the limit, while applying the 2000 version the measured vibration level is equal to 88% of the relevant limit.

The main feature of the frequency-weighted approach is its ability to better reflect the human perception of a broadband vibration. Measurements show that the new approach is very sensitive to random vibration due to propeller cavitation. The same conclusion has been

reached by Savreux *et al.* (2007), who stated that “2000 version appears more exigent for large band spectra”. Moreover, they observe that “it could be less restraining than 1984 version for some particular types of spectra presenting a concentrated energy”; this observation, in our opinion, cannot be interpreted as a good response.

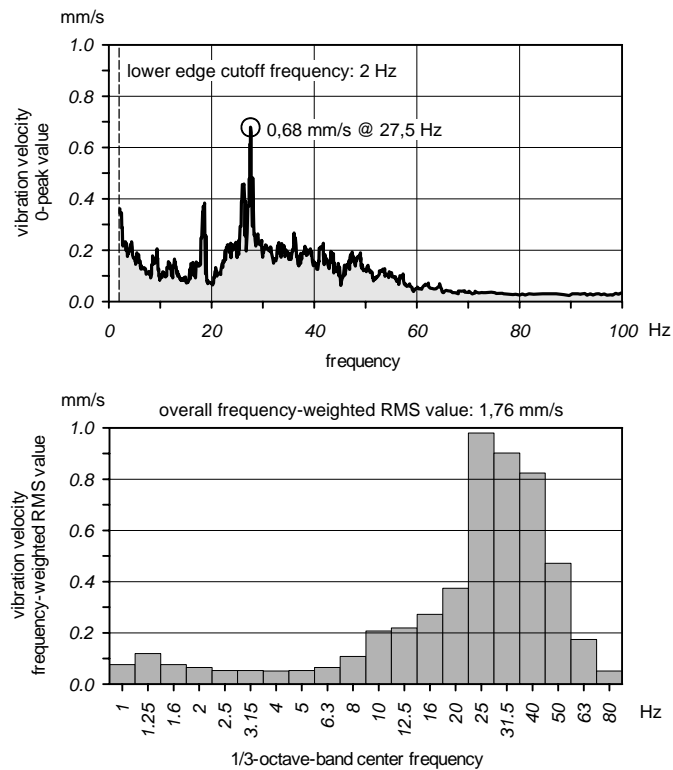


Figure 3: Spectrum with a small broadband response (cruise ship, passenger cabin).

In short, when a high content of energy is scattered on the entire bandwidth, the frequency-weighted approach clearly tends to be more reactive. This could lead to an overestimation of the vibration effects on habitability on board.

On the other hand, research carried out by Besnier *et al.* (2007) shows that in deck vibration computed according to the new ISO standard the contribution of propeller broadband excitation is insignificant compared to the contributions from 1st and 2nd propeller blade harmonic. In effect, the discomfort perception due to propeller cavitation is more related to induced structural noise than to deck vibration. Thus, the broadband approach proposed by the new ISO rule appears to be not necessary.

The new ISO standard forces designers to take a very different approach. As the concept of a comprehensive limit entails in itself manipulation of primary data, an overall level is very heavy to deal with by designers when they try to find a direct relation between vibration sources and resulting overall level. The assessment procedure of the new ISO standard is a

very demanding work, which is not at all suitable for implementation in an early stage design. Practical difficulties to sign any contract are direct consequences of such a situation. In effect, it is widely held that to define the acceptable value to be placed in a new building contract according to the new ISO rule is very hard.

Moreover, according to the 2000 version shipyards can acquire a reliable estimation of vibration-related comfort only after the elaboration of measures taken during sea trials – but this fact happens too late, when the ship is ready to be delivered and measurements are just for checking. In conclusion, a new contract where vibration limits are based on the new ISO standard cannot be managed by shipbuilders and that is enough for considering the 2000 version as an unenforceable standard.

The range of measurements from 1 Hz to 80 Hz denotes a clear disagreement with the purpose of treating habitability with reference to vibrations. In effect, our experience shows that for very low frequencies (up to 2 Hz) there are no other excitations than that of the sea. Actually, hull girder's modes up to 2 Hz may be excited by sea waves, but on the other hand hull deformations are negligible when compared to both local deformations and ship motion amplitudes. So, measurements made below around 2 Hz may just be legitimate for checking comfort in relation to sea-keeping performance of ships. Moreover, it is not true that filtering vibrations at 1 Hz has little impact on the final results.

If calm sea is a requirement for acceptance tests according to new ISO rule, it must be pointed out that waiting for calm sea conditions during sea trials would require a lot of time, which is not acceptable by shipyards. In fact, contractual measurements are made in a narrow time window, and if sea conditions are hardly acceptable, measurement outcomes are elaborated to be discussed at a later meeting between the parts.

Fulfilment of the new ISO standard is more difficult as the length of the ship decreases. Whereas old ISO 6954:1984 was applicable to merchant ships of length between perpendiculars of 100 meters or greater, the 2000 version does not provide for this eventuality. Thus, limit values are independent of ship length. Small and fast crafts have potential to produce higher noise and vibration levels than larger vessels, so it is difficult to apply the standard to all vessels. The following case cited by the ISSC 2006 Committee II.2 end referring to the work of Hung *et al.* (2004) is only given as an example.

The habitability of the living quarters and the navigation bridge of a fast craft (displacement of 200 ton, length of 30 m, and top speed of 34 knots) were assessed according to the new ISO standard. Two ship conditions have been considered. When the ship was in ballast in sea

state 2, measured frequency-weighted RMS accelerations was below the lower regulation limit, whereas in full load condition in sea state 4 close to 5, measured accelerations reached the upper limit value, because of the influence of ship motion and wave impact. Contrary to the expectations, these measurement outcomes showed an improvement in the more favourable full load condition.

In conclusion, vibration measurements according to the new ISO standard should be performed in sea state less than 2 or 3, in order to avoid unwanted effects. But, clearly, during ship trials it is not plausible to delay vibration measurements waiting for a more favourable sea state. Moreover, the above mentioned measurement campaign made on a fast craft shows a clear incompatibility, inside the new standard, between size of the ships to be applied and the admissible vibration levels.

The weak point of the old standard and best features of the new ISO standard

The real weak point of the old ISO standard is that it refers to the concept of the maximum repetitive value (MRV). That gives rise to endless discussions. The maximum repetitive (peak) value measures the highest amplitude that appears regularly in a vibration record every time dominant frequency components are in phase. Clearly, MRV concept was proposed for evaluation of the measured signal in time domain.

Nowadays, time record is not yet subject to peak identification, as collected vibration data are directly processed to obtain a time averaged narrowband spectrum of RMS values. So, the problem arises when, within the ISO 6954:1984 approach, measured RMS values need to be compared with limits expressed in terms of MRV. On the other hand, measurement equipments with appropriate filters could directly give quantities similar to peak values. Such outcomes, being obtained by averaging procedures, are not the wanted MRV unless a suited acquisition procedure would be set in order to give a standard MRV.

As stated by the 2006 ISSC Committee II.2, “MRV was not simply defined”, that leads to some uncertainty in the assessment of the vibration levels. Anyway, an MRV is also very difficult to measure if the time signal is composed of several frequencies, because it is difficult to distinguish between the MRVs relevant to the distinct frequency components.

If the signal is purely sinusoidal, measured RMS values may be converted to MRV values just by multiplying by $\sqrt{2}$. Otherwise, some approaches have been proposed to solve the question, and the simplest one is to use the so-called conversion factor C_F . Within this method, it is sufficient to multiply each value of the measured RMS spectrum by an equivalent crest factor

equal to $C_F\sqrt{2}$, where C_F is determined by calculations. If not known, a tentative value of 1.8 is proposed for C_F in the old ISO standard.

The purpose of crest factor calculation is to give a quick idea of how much impacting or beating is occurring in a time record. In shipboard vibration, impacting is often associated with wave impact, roller bearing wear, and gear tooth wear, while beating is due to the superposition of two harmonics of very similar frequencies. Crest factor gives useful information that is lost in frequency domain, where it is no more evident the difference between impacting or beating and random vibration.

If the signal analysis is carried out with a high resolution, one may infer that there is virtually just one frequency component in each frequency band, implying that C_F may be fix equal to one. Also Veritec (1985) concluded some years ago that a correction factor equal to that proposed by the standard ($C_F = 1.8$) does not lead to a correct interpretation of the measured values if the scope is to evaluate the shipboard habitability. Veritec justified such conclusion by saying that “in general, dominant components in shipboard vibration would be sinusoidal in nature”. Based on many-year experience, also the Italian Organization for Standardization (UNI) agrees on the decision of considering the value proposed by the ISO standard as not appropriate, and establishes to assume a value of one.

More recently, Toyama & Akashi (2003) showed the consistency of the old and new ISO approaches and, what is here more important, made a direct estimation of MRV on various types of signals. MRV was obtained as the average of 1/10 highest values of signal filtered by a band-pass filter. He observed that, since shipboard vibration is composed by purely periodic signals and random vibration, the larger the bandwidth the higher the values of measured MRV. Nevertheless, the outcomes show that the scatter of MRV for a “shipboard vibration” is not so high; therefore, shipboard vibration has proved to be almost purely sinusoidal.

In conclusion, if a random vibration is non-deterministic (i.e., its future behaviour cannot be precisely predicted), it is necessary to fix a good estimator of MRV. The main open question remains which should be the better estimator to be applied in shipboard vibration. Another question is the influence of beating and impacting vibrations on comfort perceived by people on board. The RMS based estimator established in the new ISO standard is clearly very useful as it can be assessed just in the frequency domain. However, such an overall value does not solve the major problem, which is to distinguish (as done by the human perception) between the effects of single harmonic excitation and broadband excitation.

The new standard is undoubtedly superior in eliminating a lot of sources of ambiguity in measurement procedures and assessment. As an example, it makes a clear distinction among different types of living areas. Moreover, following the trend of modern rules, in this guideline every step of the data collection is detailed and normalized according to ISO 8041.

Position of the classification societies

The comfort classes issued by the classification societies are based on the ISO 6954 guidelines and they set both standardized procedures and admissible values. The limits of vibration that identify the classes are different for the various Societies. Usually, for cabins on passenger ships the highest rating is lower than that of ISO 6954.

Some classification societies have accepted the point of view of shipyards and shipowners and consider opportune to postpone the implementation of the 2000 version. In other words, the new standard is considered to be not sufficiently founded, and worries about implications for shipyards and passengers are shared by the classification societies. Therefore, they allow users to optionally choose the old ISO approach instead of the new one (see Tab. 1).

Class	ISO 6954 Vibration criteria	
	1984 Version	2000 Version
ABS (2001)		✓ ⁽¹⁾
BV (2009)	✓	✓
DNV (2003)	✓	
GL (2004)		✓
LR (2009)	✓	✓
RINA (2004)	✓	

⁽¹⁾ based on BS 6841 (1987)

Table 1: Comparison of the comfort class criteria.

In DNV (2003) and RINA (2004) comfort classes, for what concerns the admissible vibration levels, reference is made to the ISO 6954:1984 approach measuring peak values in the frequency range from 5 to 100 Hz. The LR (2009) comfort class allows for both approaches, featuring two sets of vibration acceptance levels, corresponding to the old and the new ISO standard. Also the BV Comfort Class COMF-VIB 2009 gives the possibility to use the new ISO standard or the old one based on direct measuring of the peak values.

On the other hand, GL (2004) provides an overall frequency-weighted RMS level in the frequency range from 1 to 80 Hz for the habitability assessment. The same approach is

followed by ABS (2001), whose comfort class provides a maximum weighted level according to frequency weighting based on BS 6841 (1987) in the frequency range from 0.5 to 80 Hz.

In Tab. 1 the different class notations are compared in terms of applied approach and vibration limits, the latter referred to the best comfort level assigned by each class.

Regarding the noise levels, the only standards of reference existing at international scale are those issued by the International Maritime Organization (IMO), which are rules aiming at securing an acceptable level of comfort to the crew. Such standards have not undergone any modification over the years and today are sometimes considered obsolete and in some cases the noise levels required by shipowners are lower.

On the other hand, the Comfort Classes issued by the Classification Societies not only determine the maximum noise level that is to be secured for the assignment of the class, but also propose additional standardized procedures (i.e., for the measurement of the sound insulation index and of the impact sound insulation index). Nevertheless, it is the authors' opinion that the compliance with the limits for the assignment of the comfort class does not guarantee the comfort quality in the spaces on board even under normal use conditions.

Conclusions

The ideas of many European shipyards regarding the new ISO 6954 standard have been collected by the authors. They are persuaded that the 2000 version is not applicable to ships and support a deep review of the regulation assessment approach. The ISO group working to create the new ISO 20283 standard should also consider that for the new standard to be of practical use a series of prerequisites are essential, that is ease identification of the exciting sources and repeatability and reliability of measurements.

Moreover, the future ISO standard should be based on a more manageable assessment procedure. In fact, as matters stand, it is very difficult for shipbuilders to sign new building contracts based on acceptable vibration limits according to ISO.

It is also clear that a better understanding of the mechanism which governs the comfort perception is necessary for defining more reliable assessment standards. Thus, definitive study should be encouraged to clarify how distribution and amplitude of excitation frequencies of a spectral distribution affect the passengers comfort on board of a ship.

In the meantime, the old ISO approach should be regarded as more appropriate to make design predictions and to exploit the experience acquired by the shipyards to full advantage of the real comfort. However, experience of designers suggests that the old ISO 6954:1984 is

very effective. In fact, shipowners too still consider valid the methodology provided by the old ISO standard, which they conservatively take as reference, reducing its limits and differentiating them between the areas devoted to passengers and those devoted to the crew.

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