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Some Notes on "SES" Hull Structural Design According to Classification Rules

Tadeusz JASTRZEBSKI, Zbigniew SEKULSKI
Faculty of Maritime Technology, Technical University of Szczecin,
Al. Piastow 41, 71-065 SZCZECIN, Poland

ABSTRACT

The paper deals with the structural hull design of Surface Effect Ships (SES). Results of the authors' investigations on the subject are presented. At first a general examination and a comparison of several rules and codes is done. The attention is given to the ship structure types and design loads - local and global type loads and accelerations. The main criteria and the field of their application are demonstrated. Rule formulas are performed and compared. Next the results of the numerical analysis and parametric study are presented. The main data of the material and structure geometric model of SES L=60 m are shown. Some particular results concerning minimum thickness, overall strength and accelerations are shown for different structure types. Various stucture systems (longitudinal and transverse) and materials (steels and aluminium alloys) are concerned. The final mass comparison for those models is given together with some concluding remarks and suggestions for the design, rule development and further research works.

1. INTRODUCTION

The subject of hull structure design of Surface Effect Ships is under investigation in some world design and research centres. Also on the forum of the International Ship and Offshore Structures Congress (ISSC) the specialists committee (Committee V.4 - Surface Effect Ships) directed its work mandate to SES since 1991. But the dynamically supported crafts, including SES, by their very novelty and because of their small number, have still many problems peculiar to themselves. The question arrises: "What about the applicability of classification rules to SES structural design?"

In the paper we are listing the main design topics which one can face when the "rule based hull design" is proposed to be used to

the SES hull members dimensioning. We also try to demonstrate some particular differences and similarities between requirements of the chosen classificaton rules and their applicability in the case of a SES structure.
So we are dealing with the overall behaviour of a SES hull and we compare formulae for longitudinal vertical bending, transverse vertical bending, transverse torsion and vertical accelerations.
On the base of existing rule formulae the parametric study for a SES hull model of the length of 60m was carried out. For this model we assumed longitudinal and transverse stiffening systems and we calculated all main hull members for a module of 7.2 m length. Collected data were used for the mass analysis so we demonstrate in the paper the mass comparison for different steel and aluminium alloy materials according to the different classification rules' requirements. The results were used to formulate some general remarks. But the resulting figures illustrate some trends only and one can expect different results for any other models, materials or codes.

2. REVIEW OF RULES AND CODES

2.1 General remarks on codes' applicability to SES

It is well known, that in most ship and offshore projects the very beginning step of the hull structure design is generaly based on classification codes requirements (so called "rule design"). This constitute a simplified solution but it is still an attractive approach for many reasons, like a shortening of the design men-hours, not sophisticated design formulae and calculations etc. This solution is also very convenient when a new type structure is to be designed or if a new team of designers, let us say a "team of beginners", undertakes the design work; it is commonly judged that in such a case by utilization of the classification rules some "big mistakes" can be avoided and the designed structure may be assured to have an international safety standard.

In the field concerned, there are several codes accessible, like those of BUREAU VERITAS (BV) 1990, DET NORSKE VERITAS (DnV) 1985, GERMANISCHER LLOYD (GL) 1991, INTERNATIONAL MARTIME ORGANIZATION (IMO-IMCO) 1977 and LLOYD'S REGISTER (LR) 1979-1991. Their philosophy and theoretical and practical basis were the subject of some earlier publications, for example by FAULKNER 1992 and MARCHANT 1992. Some rules may be treated for rather a local destination, being edited in national versions only, like the rules of MINISTRY OF TRANSPORT OF JAPAN and KOREAN REGISTER OF SHIPPING. And finaly let us note that it was announced at many occasions that a number of codes are nowadays under the revision work - IMO, GL and others.

In this paper five codes are of our interest: IMO, BV, DnV, GL, and LR. In the rules one can find several definitions dealing with ship and hull types in connection with the SES. For example IMO Code defines "Dynamically Supported Side Wall Crafts", which may be "An air-cusion vehicle whose walls - extending along the sides - are permanently immersed hard structure". The Dnv rules present the same definition and include the "Side Wall Craft" to the different types of "High Speed Light Crafts" - Figure 1.

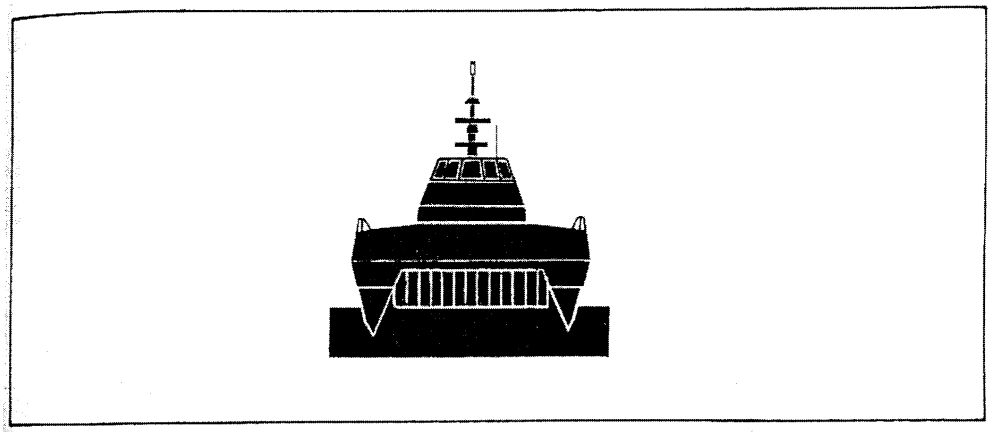

Figure 1. Surface Effect Ship (Side Wall Craft - Air Cusion Catamaran)

Not all codes give a clear and direct statements according their applicability to the SES type structures. This is demonstrated in the Table 1. The ship types and main criteria - speed, length and displacement are compared there too. One can note that only IMO, BV and DnV rules are directly "SES-oriented".

2.2 Design loads assumptions

In most rules load assumptions are based on the unified wave height. It equals to the mean of the greatest third of wave heights within the wave spectrum. All rules provide hull girder global load formulation basing on the simple beam theory and the formulae for longitudinal bending moments, transverse vertical shear forces and bending moments, pitch connecting moments and vertical acceleration are advocated for designers' needs - Figure 2, Tables 2 and 3.

Table 1. Applicability of codes to SES structures

No.	CODE	TYPE OF SHIPS CONCERNED			APPLICATION FIELD CRITERIA		
		AIR-CUSHION VEHICLE	TWO-HULL VEHICLE	SES	SPEED kn	LENGTH m	DISPLACEMENT t
1	IMO	YES	YES	YES	$\frac{v}{\sqrt{gL}}>0.9$	NO LIMITS	NO LIMITS
2	BV	YES	YES	YES	$v>4\sqrt{L}$	12-50	NO LIMITS
3	DnV	YES	YES	YES	$v > 20$	12-50	$\Delta<(0.13LB)^{1.5}$
4	GL	?	YES	?	$v>V_n$ *)	NO LIMITS	NO LIMITS
5	LR 1970	YES	?	?	NO LIMITS	NO LIMITS	NO LIMITS
6	LR 1991	?	YES	?	$v > 20$	$L > 15$	NO LIMITS

*) v_n - speed of normal seagoing ship.

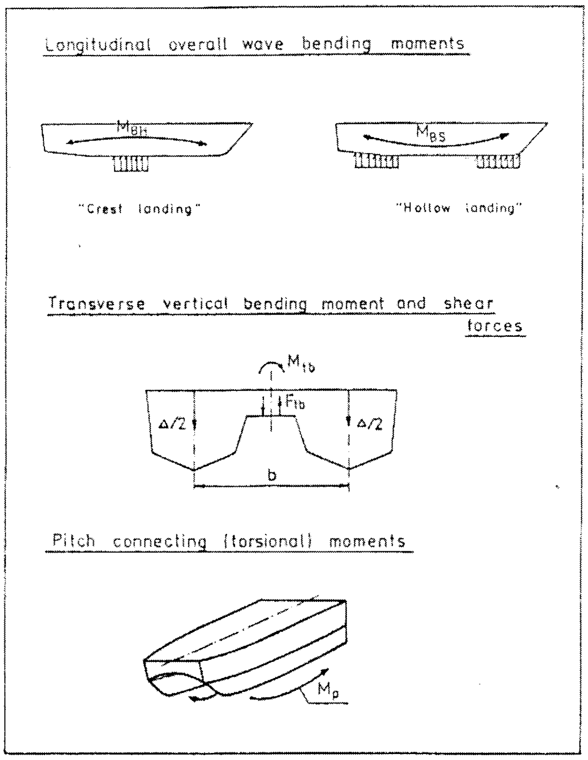

Figure 2. Hull girder global loads

But not all codes (BV, GL) give the clear reccomendations and formulae for the design slamming preassures which are so essential when SES structure is concerned on sea states.

Table 2. Tween hull effects - overal strength

No.	LOADS	FORMULAE			
		BV	DnV	GL	LR
1	Transverse bending moment	$M_{TL}=\frac{\Delta b}{7}\gamma_m$	$M_S=\frac{\Delta b}{4}a_v$	$M_{tb}=\frac{\Delta b}{4}g$	$M_B=2.5\Delta b\cdot a_v$
2	Vertical shear force	$T_{TL}=\frac{\Delta}{5}\gamma_m$	$S=\frac{\Delta}{q}a_v$	$F_{tb}=\frac{\Delta}{3}g$	$Q=2.5\Delta\cdot a_v$
3	Torsional (pitch connecting) moment	$G=\frac{\Delta L}{12}\gamma_m$	$M_p=\frac{\Delta L}{8}a_v$	$M_{tt}=1.25\Delta L$	$M_T=2.5\Delta L_s a_v$

Table 3. Rule formulae for vertical acceleration

No.	CODE	BASIC FORMULA
1	BV *)	$\left(1+0.1\frac{V}{\sqrt{L}}\right)g$
2	DnV *)	$\frac{k_v\cdot g_0}{3458}\left(\frac{H_s}{B_{WL}}+0.084\right)\frac{\tau}{4}\left(50-\beta_{cg}\right)\cdot\left(\frac{V}{\sqrt{L}}\right)^2\frac{LB_{WL}^2}{\Delta}$
3	GL **)	$\frac{0.22\cdot v}{\sqrt{L}}\cdot mg$
4	LR *)	$\nabla_A\theta_B L_1(H_1+0.084)(7-0.1\theta_D)\left(V/\sqrt{L_{WL}}\right)^2\cdot 10^{-3}g$

*) at longitudinal centre of gravity,
**) at midship section.

3. PARAMETRIC STUDY OF "SES-600" MODEL

3.1 Ship hull model data

In the Figure 3 the cross section and principal dimensions of a SES-600 model proposed by SCHLACHTER, 1992a are shown. The model was used by NISHIMARA, 1992 in the numerical parametric analysis. Two stiffening - transverse and longitudinal - systems were taken into consideration, and a module of the length of 7.2 m was used in the mass comparative study. Simple microcomputer programmes were developed and the systematic calculations were made. The material data for the three steel and two aluminium alloy grades are given in Table 4.

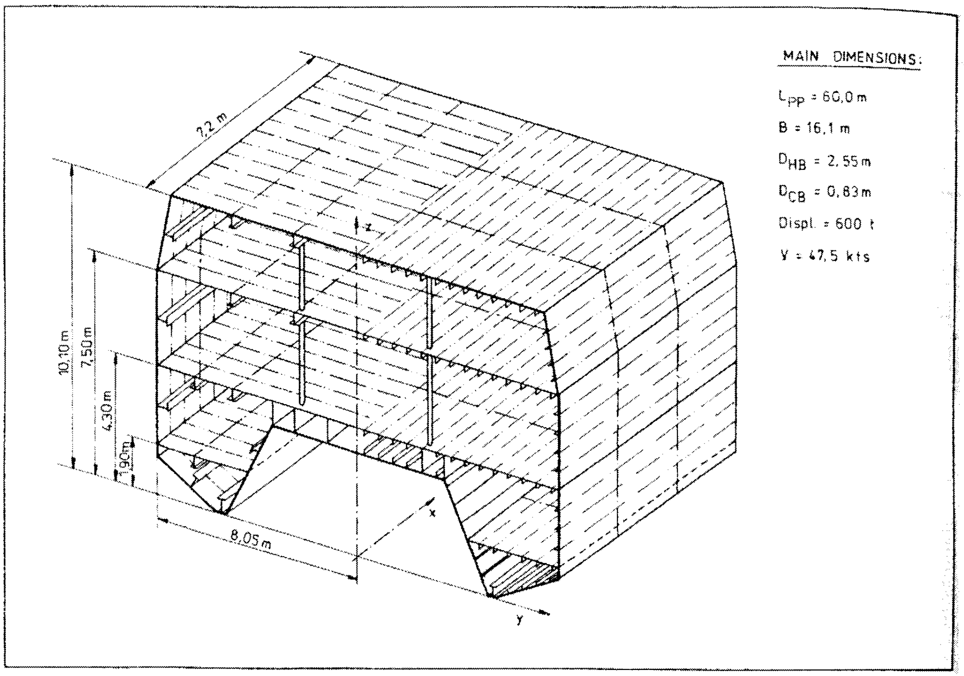

Figure 3. Hull model of SES-600

Table 4. Material data for structure parametric study

No.	MATERIAL TYPE	R_e MPa	R_m MPa	MATERIAL FACTOR (k,f)			
				BV	DnV	GL	LR
1	MILD STEEL (MS)	235	446 (402÷491)	1.00	1.00	1.00	1.00
2	HIGH TENSILE STEEL - HTS32	315	530 (471÷589)	0.79	1.28 (0.78)	0.78	0.75
3	HIGH TENSILE STEEL - HTS36	355	555 (491÷618)	0.72	1.39 (0.72)	0.72	0.66
4	ALUMINIUM ALLOY - 5086 - H112 (Al1)	110*	240	2.16	0.46 (2.19)	1.81	2.14
5	ALUMINIUM ALLOY - 5083 - H321 (Al2)	165*	275	1.48	0.68 (1.45)	1.44	1.42

*$R_{0.2}$
R_e - yield stress, minimum,
R_m - ultimate strength, average and range.

The comparison of the corresponding material factors for scantling analysis is shown in the same table. No significant scattering of the values, with the exception of one of alluminium grades according to the GL rules, is observed.

3.2 Minimum thickness

In all investigated classification rules the minimum thickness formulae are recommended for various plated structure types - bottom, side shell and decks. But only DnV and LR rules make the thickness dependent of mechanical material properties. In Table 5 the scatter of minimum thickness values is presented for five material grades concerned in this work. It may be noted that the range of extreme results is quite significant and it seems to be not well substantiated.

Table 5. Minimum rule thickness for plating of SES-600

No.	MATERIAL	BOTTOM SHELL mm	SIDE SHELL mm	STRENGTH DECK mm
1	MS	4.9 - 5.4 * 0.5 **	4.1 - 5.9 1.8	2.5 - 4.9 2.4
2	HTS 32	4.2 - 5.4 1.2	4.0 - 5.4 2.4	2.5 - 4.2 1.7
3	HTS 36	4.0 - 5.4 1.4	4.0 - 5.4 2.4	2.5 - 4.2 1.7
4	Al 1	5.0 - 7.1 2.1	4.5 - 8.6 4.1	2.5 - 7.1 4.6
5	Al 2	5.0 - 5.8 0.8	4.5 - 7.0 2.5	2.5 - 5.8 3.3

*Min-Max, **Range

3.3 Transverse bending, torsion and vertical acceleration

Transverse overall hull loads expressed by the rule formulae - vertical shear forces, bending moments and torsional (pitch connecting) moments are lineary depending of the acceleration - Table 2. So at first the vertical hull acceleration amidships was calculated. In Table 6 the results according to rule formulae are compared with some computer analysis results. The linear and nonlinear theory was applied and results given by SCHLACHTER, 1992b and NISHIHARA, 1992 are quoted here. The results variation is very notable and requires some further calibration of the calculation

methods for the design purposes.
The next Table 7 shows the comparison of results for transverse bending and torsion hull loadings calculated for the erlier computed accelerations. The differences are also remarkable but someone should analyse those results together with the design formulae for dimensioning of local strength members.

Table 6. Vertical acceleration - Rule values and computer calculations for SES-600

	CALCULATION METHOD	VALUES MULTIPLES OF g
	Rule values	
1.	BV	1.58
2.	DnV	0.76
3.	GL	1.02
4.	LR	0.54
	Computer results, $H_{1/3}$ = 4 m	
5.	DYNBEL - linear Hull borne	0.192
6.	DYNBEL - nonlinear Hull borne	0.646
7.	SEAKP Cushion borne	0.681
8.	DYNBEL - linear Cushion borne	1.047
9.	DYNBEL - nonlinear Cushion borne	1.057

Table 7. Calculation results of tween hull effects for SES-600

No	LOADS	BV	DnV	GL	LR
1.	Transverse bending moment, MNm	17.22	14.50	19.08	19.45
2.	Vertical shear force, MN	2.03	1.62	2.14	1.63
3.	Torsional (pitch connecting) moment, MNm	50.65	36.55	49.04	49.04

3.4 Mass of hull modules

The principal and secondary hull memmbers were dimensioned in accordance with BV, DnV, GL and LR rule formulae. Transverse and longitudinal strength member systems were investigated. The mass of the modules of 7.2 m length were computed and the graphical presentation of results is shown in Figures 4, 5 and 6.

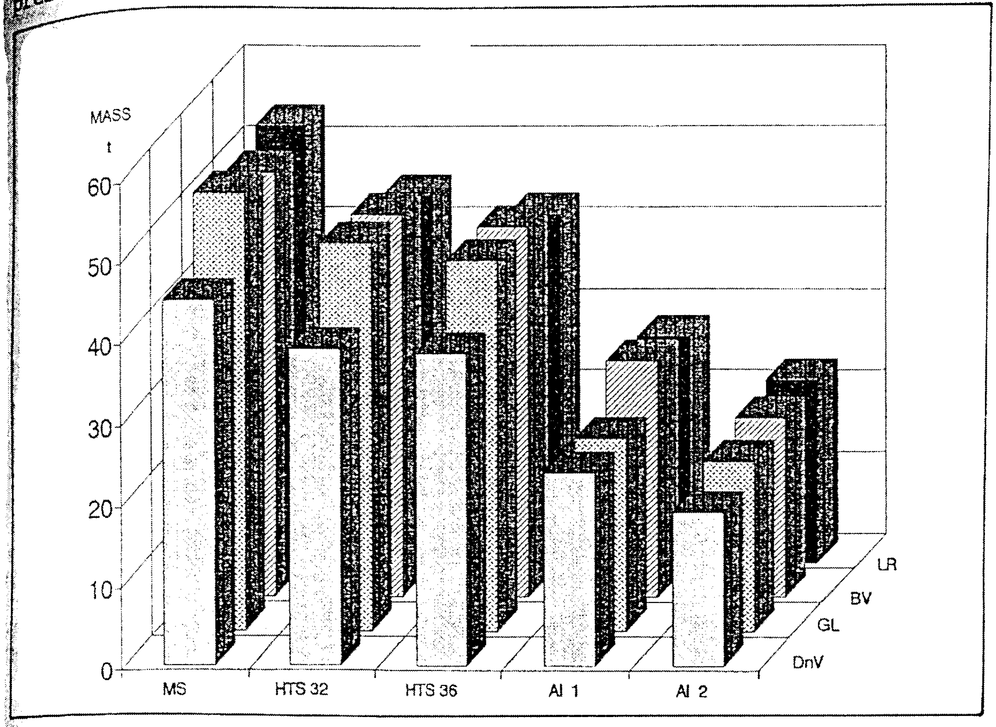

Figure 4. Mass calculation comparative study results for SES-600. Module 7.2m length - transverse stiffening system

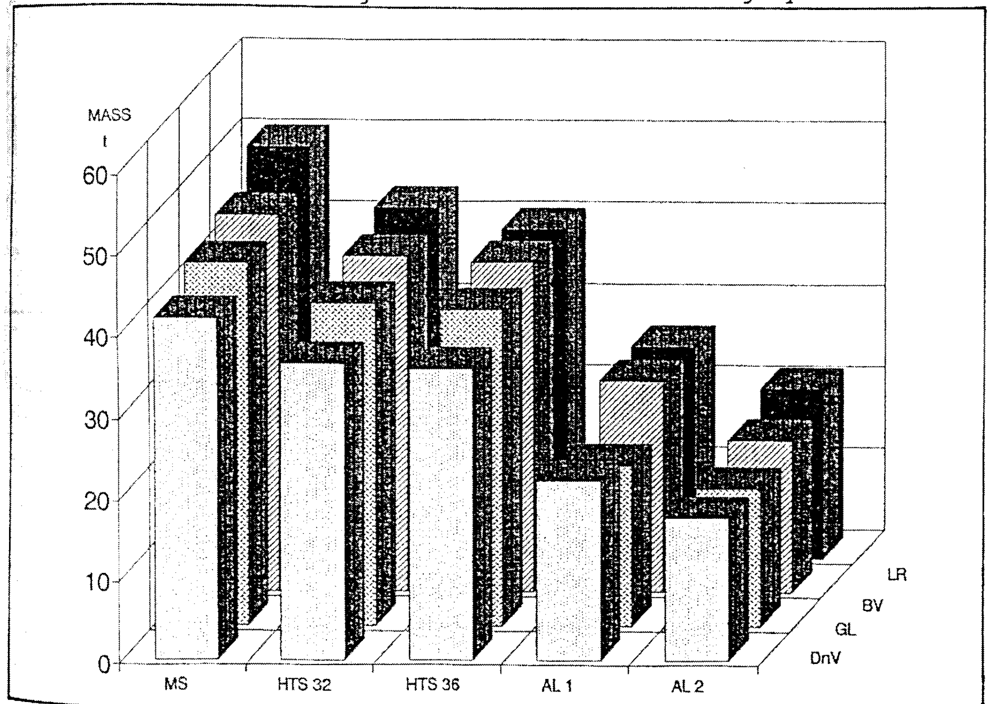

Figure 5. Mass calculation comparative study results for SES-600. Module 7.2m length - longitudinal stiffening system

The general tendency of mass reduction due to the light alloys and higher strength materials applied in the structures is well demonstrated. This may be adressed to the decision makers, to their early design analysis when the material selection is considered. The variation according to classification codes applied in the analysis does not have be so far set off because of the rule restrictions mentioned in chapter 2.

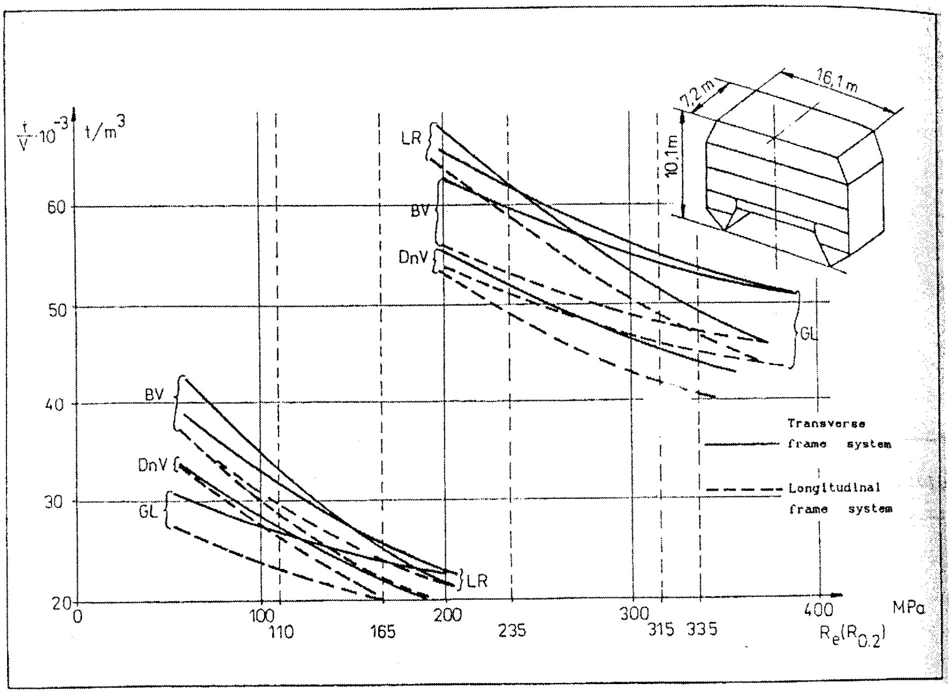

Figure 6. Mass coefficient for SES-600

4. CONCLUDING REMARKS

Several design codes were examined and applied into design procedure of an example hull model of the Surface Effect Ship. The applicability of the codes was studied and some differences in rule approach and formulae were demonstrated. So it was proved that for the ship type concerned some further works are needed and they should be devoted to the unification of international structural safety standards.

We also have to adress a remark to the designers that the "rule design" in the SES case may constitute the first, preliminary step only and hull load numerical assesment and 2-D and 3-D FEM structural analysis are obvious practicaly for most SES structures.

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REFERENCES

BUREAU VERITAS (1987) Rules and Regulations for the Classification of Light Highspeed Ships, Paris.

DET NORSKE VERITAS (1990), Rules for Classification of High S' 'd Light Craft, Oslo.

FAULKNER D. (1992) Classification Societies - Are they up-to-date? Third Conference on High Speed Marine Craft, Kristiansand.

GERMANISHER LLOYD (1991) Rules for Classification and Construction Ship Technology - Seagoing Ships - High Speed Vessels, Hamburg.

INTERNATIONAL MARTIME ORGANIZATION (1977) Resolution A.373(X), IMCO.

LLOYD'S REGISTER OF SHIPPING (1979) Guidance Notes and Requirements for the Classification af Air Cushion Vehicles (ACV), London.

LLOYD'S REGISTER (1991) Provisional Rules for the Classification of High Speed Catamarans, London.

MARCHANT A. (1992) Structural Design Philosophy for High-Speed Passenger Craft. International Seminar on "Safety for High-Speed Passenger Craft - The Way Ahead", RINA, London.

NISHIHARA S. (1992) SES-600. Load Calculations. Mitsui Eng. and Shipb., (not published report, for ISSC-Com.V4 use only).

SCHLACHTER G. (1992) SES-600. Load Assumptions and Calculations. Hamburg (not published report, for ISSC-Com.V4 use only), Hamburg.

SCHLACHTER G. (1992) Technical data of 60m passenger-car ferry (SES-600). Marinetechnik GmbH, Hamburg.