High speed pod propulsion – Application and Integration

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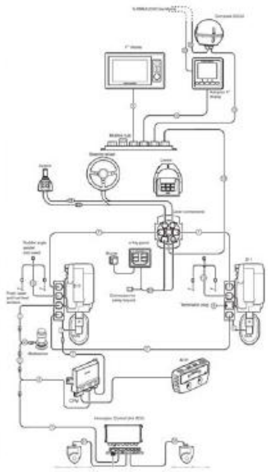
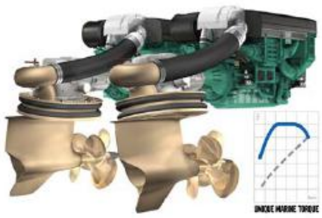
VOLVO
PENTA

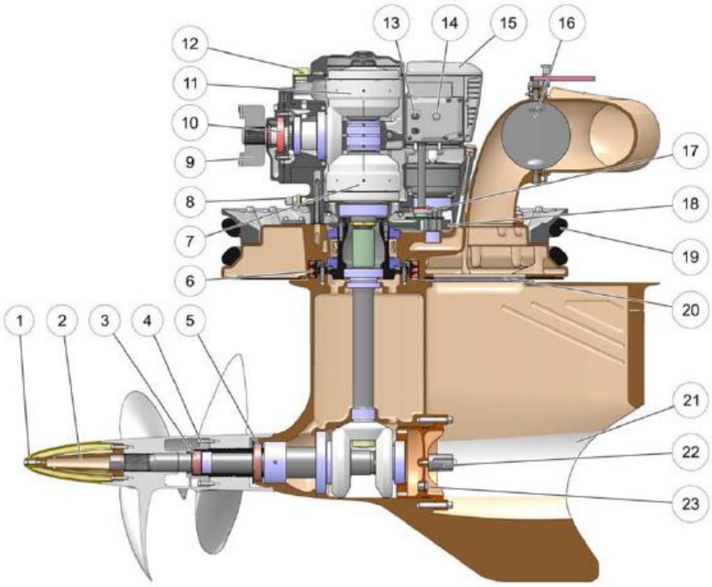
Fully developed system from Propeller to Antenna

Larger system = more responsibility = closer cooperation



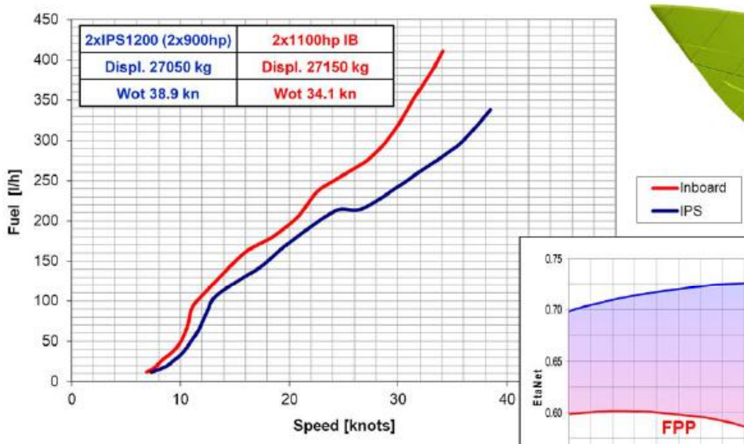


IPS hardware

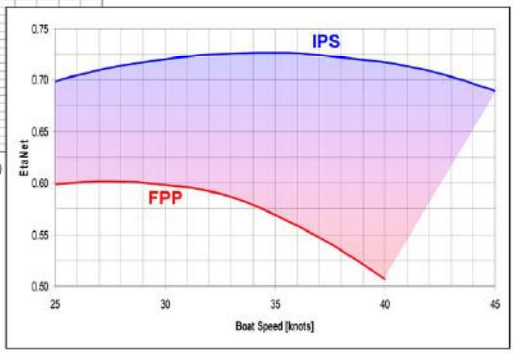


VOLVO
PENTA

Efficiency



2xIPS1200 (2x900hp)
Displ. 27050 kg
Wot 38.9 kn
2x1100hp IB
Displ. 27150 kg
Wot 34.1 kn
Fuel [l/h]
Speed [knots]
Inboard
IPS



IPS
FPP
EtaNet
Boat Speed [knots]

Speed/application window

Maximum speed application window 20 to 40+ knots

Name	IPS900	IPS1050	IPS1050	IPS1200
Power, ratio, rpm	D13-700, 1.99, 2250	D13-800, 1.99, 2300	D13-800, 1.88, 2300	D13-900, 1.88, 2300
Propeller range	QS5-Q7	QS5-Q7	Q1-Q7	Q2-Q7
Boat speed*	20.7-37.2kn	20.3-37.3kn	26.1-41.4kn	27.1-40.2kn

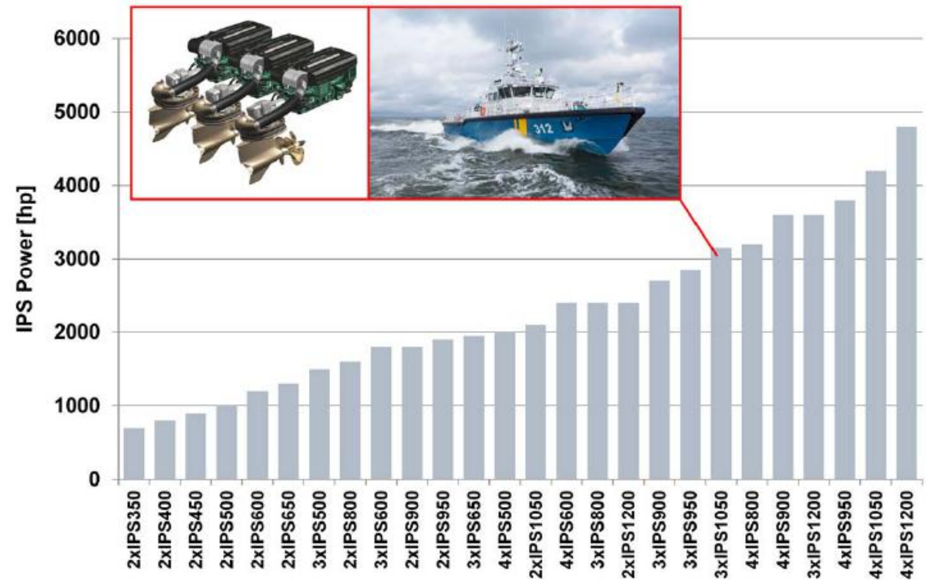
Name	IPS650	IPS800	IPS800	IPS800	IPS900	IPS950
Power, ratio, rpm	D11-510, 1.70, 2250	D11-600, 1.59, 2300	D11-600, 1.70, 2300	D11-625, 1.70, 2400	D11-700, 1.59, 2350	D11-725, 1.70, 2500
Propeller range	PS4-P7	P2-P7	PS4-P7	PS4-P7	(P1) P2-P7	P1-P7
Boat speed*	18.7-37.3kn	28.7-41.6kn	17.8-37.1kn	19.9-39.7kn	28.2-41.5	27.7-41.1

Name	IPS350	IPS400	IPS400MC	IPS450	IPS500	IPS600
Power, ratio, rpm	D4-260, 2.08, 3500	D4-300, 2.08, 3500	D6-310, 1.94, 3500	D6-330, 1.94, 3500	D6-370, 1.94, 3500	D6-435, 1.82, 3500
Propeller range	TS3-T10	TS3-T10	TS3-T10	TS3-T10	TS3-T10	TS3-T10
Boat speed*	17.5-44kn	15.5-42.3kn	19.4-47.8kn	18.6-47.1kn	16.9-45.7kn	18.5-49.2kn

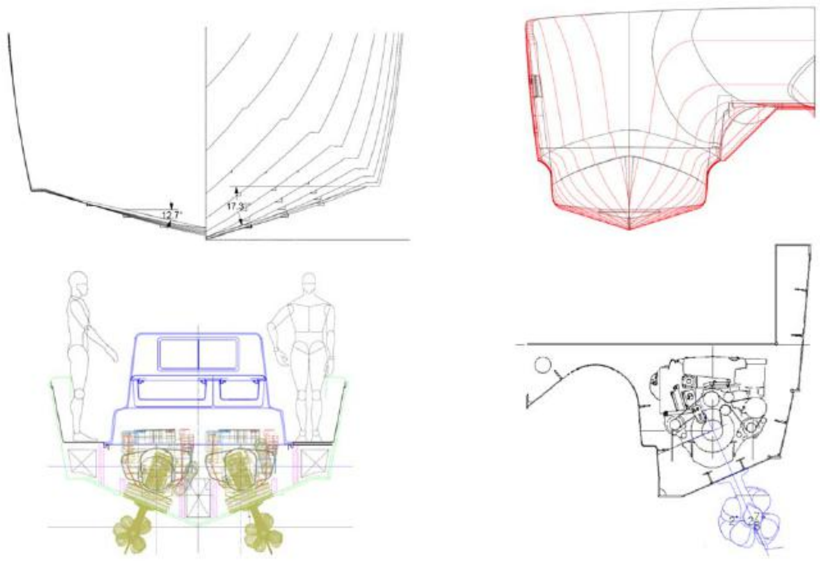
* Approx. boat speed at engine rated speed

Volvo Penta can NOT deliver outside indicated range.

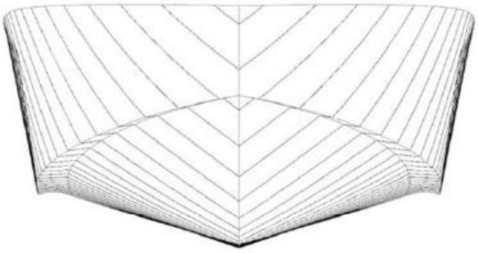
Product configurations and power range



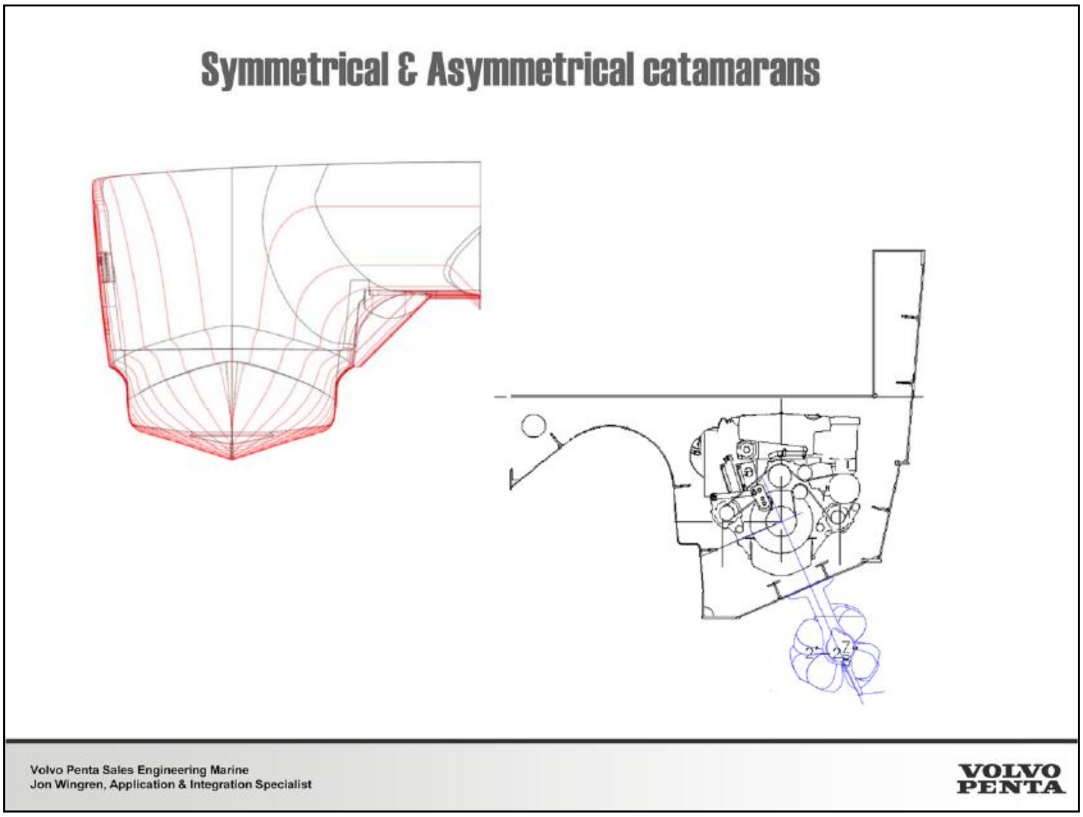
Experience of different hull shapes



Monohull

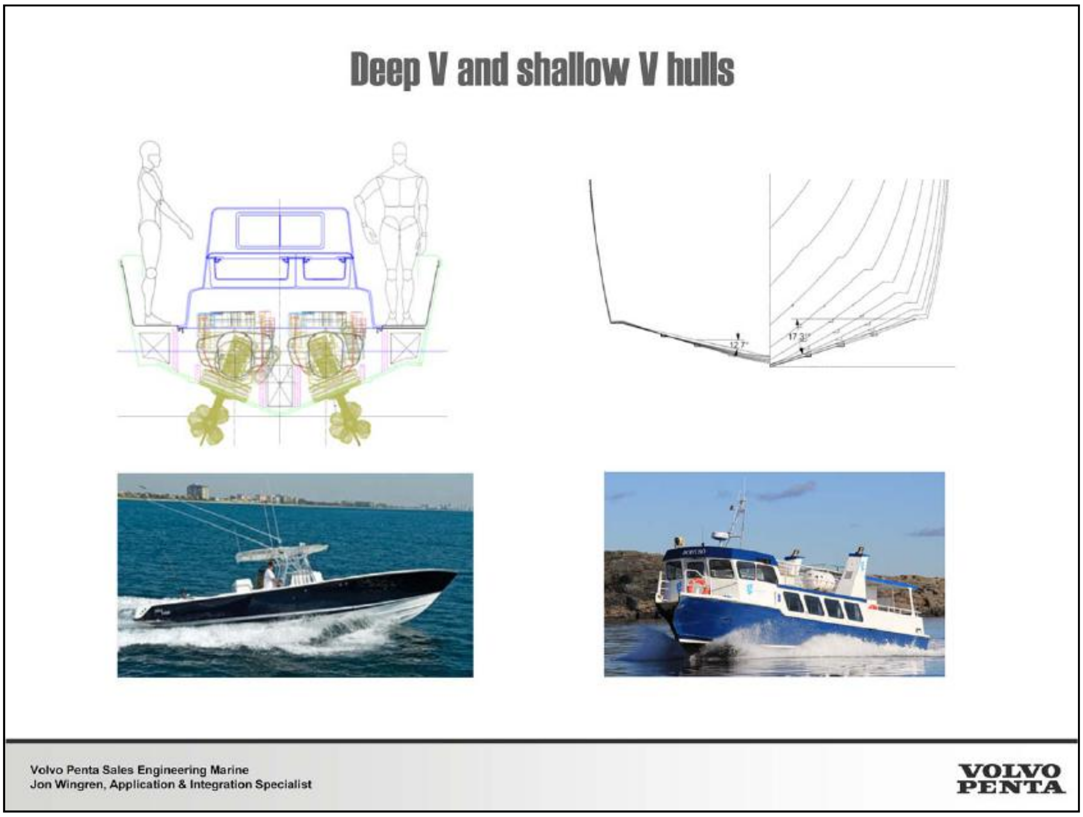


The IPS system was designed around a monohull shape. Steering configurations, drawings, testing, etc. was made for monohull shapes and there are remnants left in the software due to this. However, the vast number of samples have clearly shown that almost any hull shape is applicable.



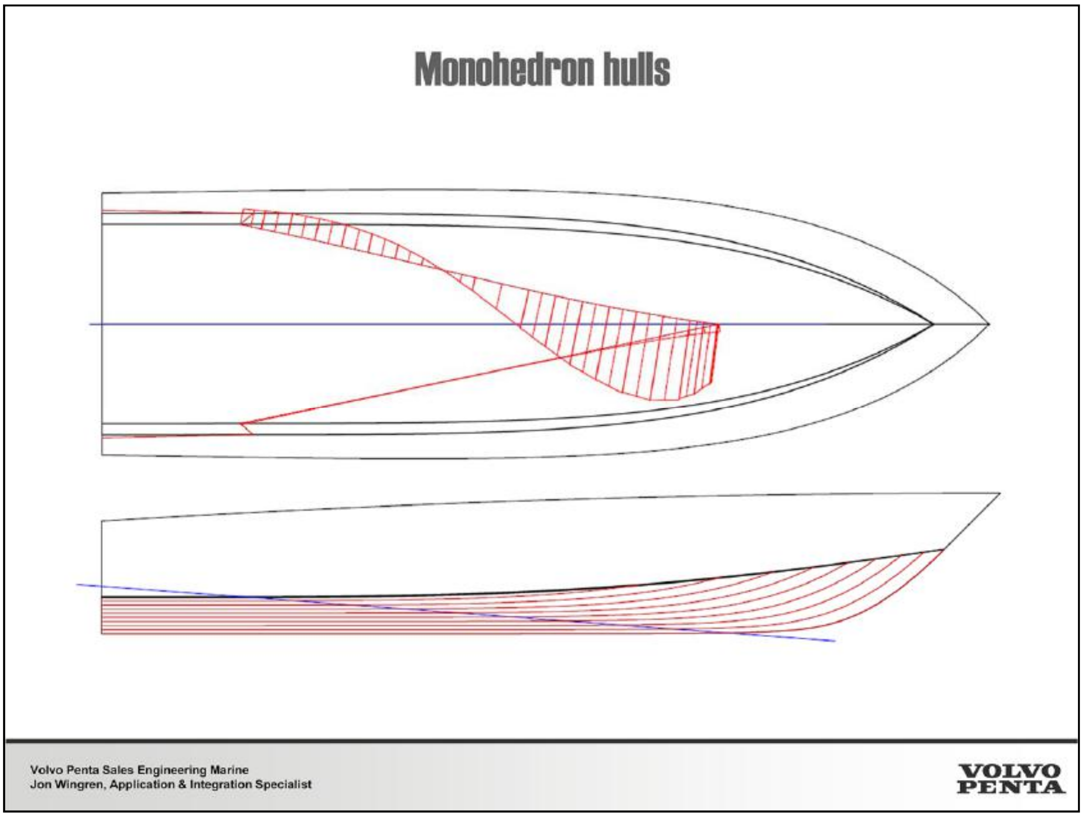
The symmetrical catamaran is suitable with IPS and will in most cases have the units fitted without deadrise (vertical). This means that some information needs interpretation, example: installation drawing toe-in angle. Steering modes may be limited, several cases with large beam vessels require minimum steering setting.

The asymmetrical catamaran hull is very suitable with IPS but the demi-hulls will in most cases be rather narrow in comparison to symmetrical installations and may be a difficult integration due to service and articulation requirements. Asymmetrical catamarans are normally less efficient than symmetrical, unless very tuned or supported by other assistance, such as foils.

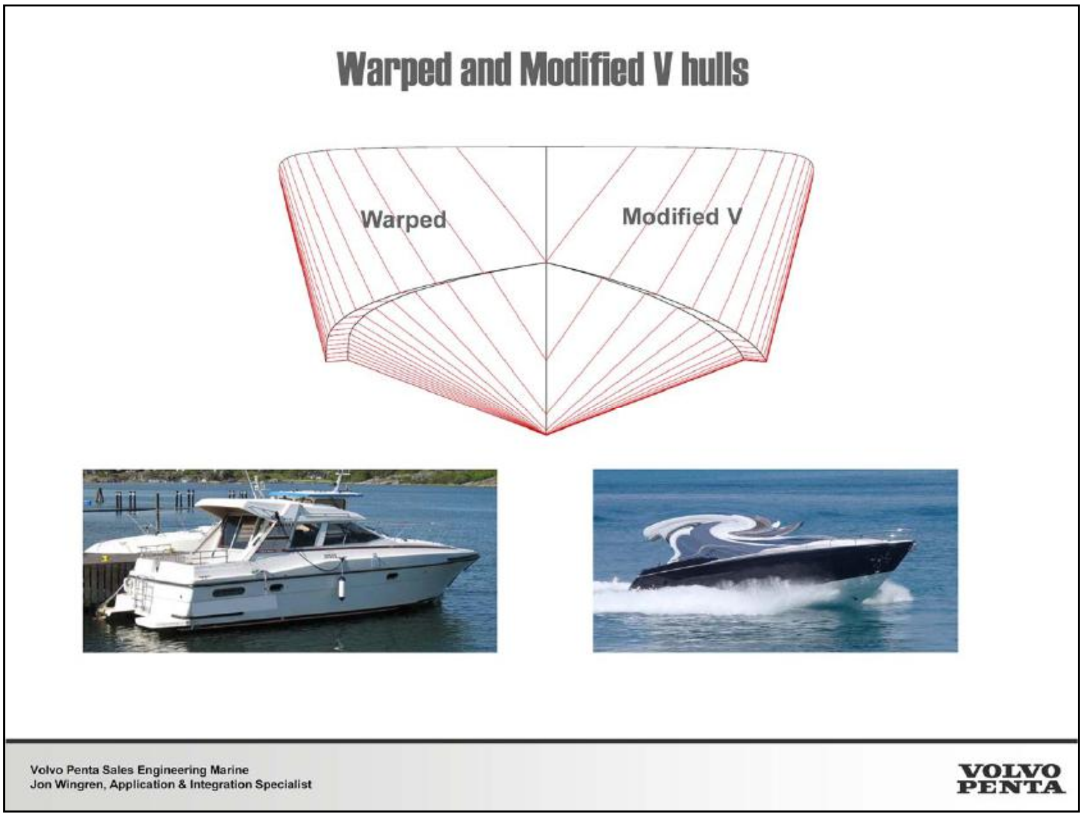


The deep V is a well functioning hull shape for IPS although the high deadrise, normally above 18-20deg, will allow the IPS to generate substantial rolling moments. A deep V hull must be combined with a low center of gravity and/or aggressive chines to maintain comfortable turning characteristics in combination with IPS.

The low deadrise hull has some good qualities in combination with IPS due to its properties of reduced induced rolling moment and high initial stability. However, since boats with low deadrise run at low trim angles at high speed they may suffer from dynamic instabilities tendencies and articulating pods exaggerates heel and in many cases increases top speed. It may in some cases be difficult to balance these hulls, both transversally but also longitudinally.

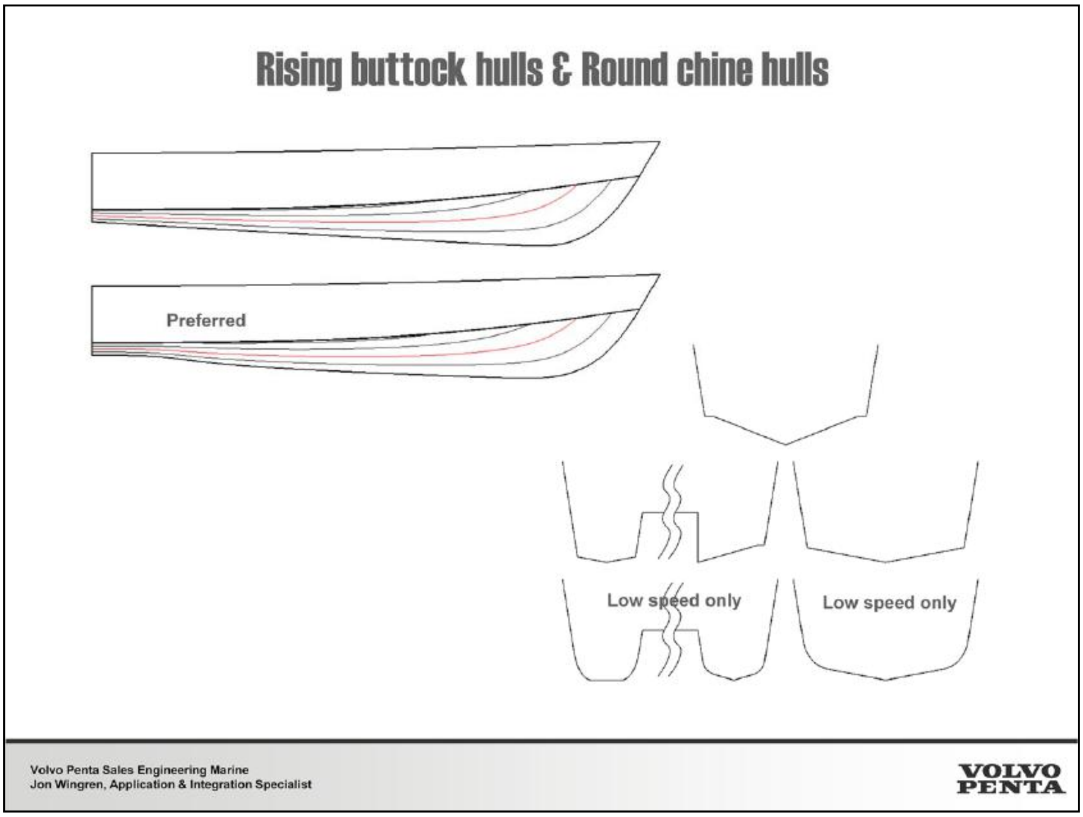


The monohedron (aka constant deadrise = parallel buttock lines) hull shape has for a long time been considered the most efficient shape for planing boats (without transversal steps). It has been seen in VP testing that it is also the best performer in combination with IPS. The negative aspect is that it requires a rather high deadrise to produce a comfortable ride which means that the rolling moment of IPS is introduced. A well balanced monohedron shape with low vertical center of gravity and slightly above normal chines will produce a very nice IPS application.



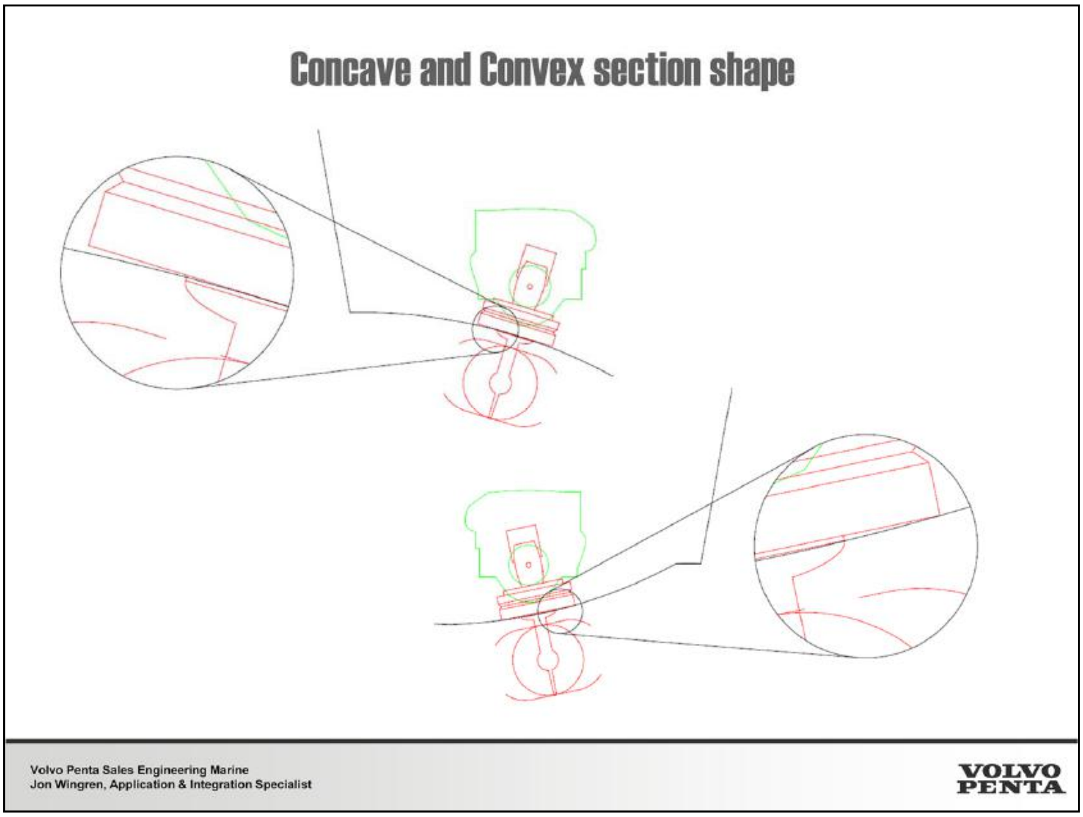
The warped hull was the first planing hull type. It is good for low planing speeds and is suitable for carrying weight far aft. The negative aspects are that the behavior is somewhat unpredictable especially when turning with typically reduced trim angles and longitudinal trim change over speed is usually exaggerated due to the balance of the boat.

The modified V is a good contender of what might be considered the most popular IPS hull. It combines the sharp entry of the warped hull while the change in deadrise is rather small which is favorable for efficiency. Most versions of this hull shape also have straight sections which makes the integration with IPS simpler.



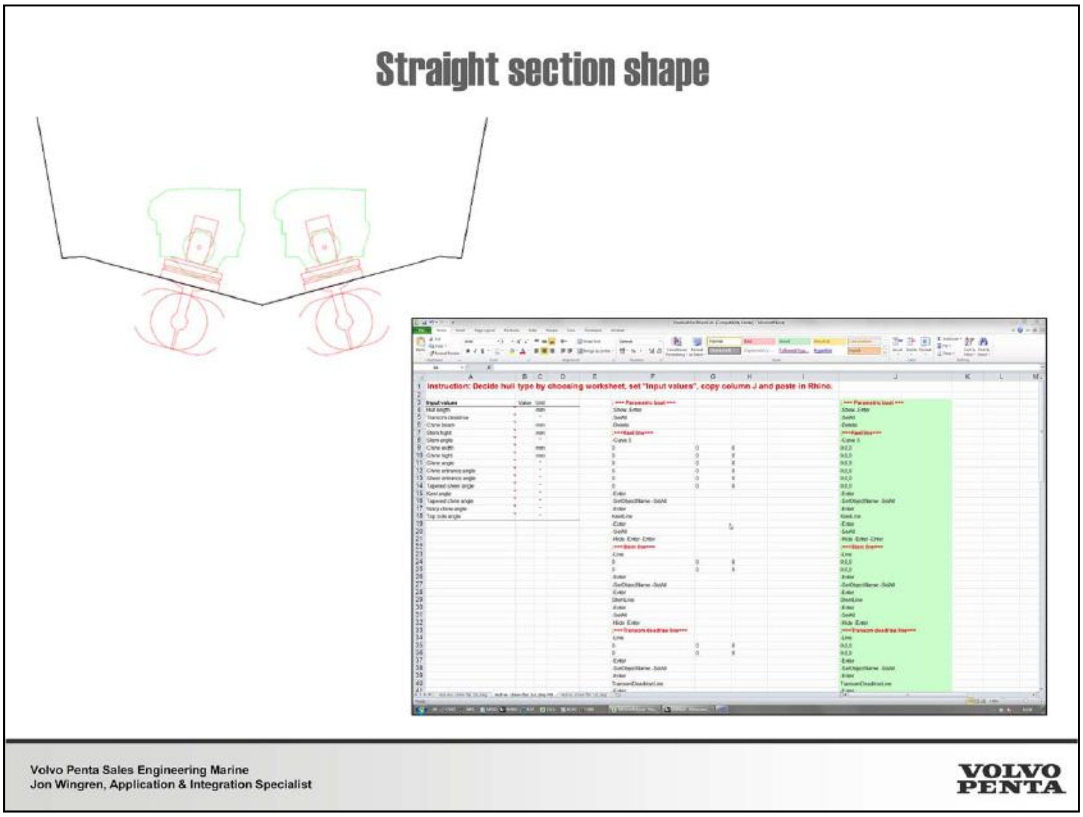
The traditional rising buttock hull, typically applied in low speed boats (semi-planing high efficiency) has been judged to work well in configuration with IPS given a relatively low speed, around or below FnV=2.6. However the IPS units tested have so far been fitted close to horizontally. This works with benefit to both the thrust angle of IPS but also to give a slight pressure increase to the hulls dynamic balance which in many cases reduces hull drag.

A round chine hull is normally not suited to high speed applications. As for IPS, it is to be avoided unless the speed is kept at a minimum and vertical center of gravity is low in comparison to effective width (natural with catamaran). Risk of air interfering with the propellers and steering may be affected. Poor efficiency, sudden rpm increase or steering ocillations may be the result.



A <u>concave</u> section shape will improve transverse dynamic stability for low to medium speed applications and also improve small sea state comfort but may also reduce efficiency. The section must not be concave in the area immediately next to or in the interface of the IPS. If this is the case it is likely the unit will mechanically interfere with the hull and the steering forces may be exaggerated.

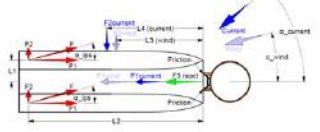
A <u>convex</u> hull has good planing efficiency but is very poor at generating transverse dynamic stability and in some cases also course stability. It normally requires very large reverse angle chine flats to compensate for the lack of stability, even more so in combination with pod propulsion. The convex shape will also make it difficult to integrate the IPS unit. It is very likely that the result will be negative, similar to the concave shape.



A straight section shape will by far be the simplest to integrate IPS with. It is easy to predict and check and will in most unspecific cases be most efficient. VP recommends this section shape to be the geometric starting point.

IPS integration process and involvement from Volvo Penta, 1

BOAT DESIGN STAGE

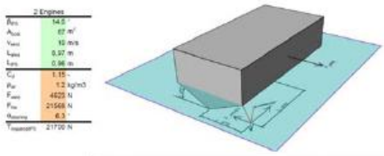


• Input: 3D hull + accurate load data, VP can arrange for scale weighing of current model if needed

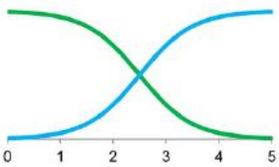
• Processing: speed, trim, performance liabilities, geometric aspects, GA considerations

• Result: IPS prospect review report (to OEM/MU)

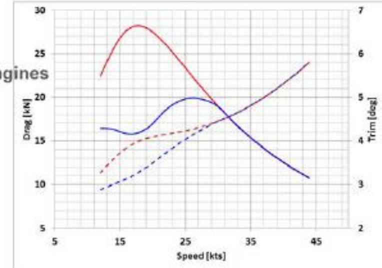
• . . . secondary reviews based modified data.



$$RF2.0 = k_1\left(1 - 1/e^{5-2F_{nV}}\right) + (k_2 + k_3 + k_4)\,1/e^{5-2F_{nV}}$$



Points of technical review
- Main hull geometry
- Load cases
- Location of IPS units/engines
- Structural solution
- Specific hull geometry
- Speed prediction
- Trim prediction
- Fuel prediction
- Joystick analysis
- Bottom loading
- Stability index
- Roll factor 2.0



OEM = Boat builder, MU = Volvo Penta Market Unit, SEM = Volvo Penta Sales Engineering Marine

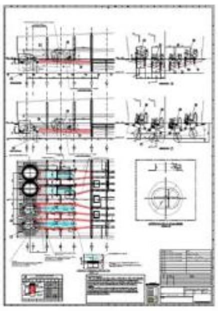
IPS integration process and involvement from Volvo Penta, 2

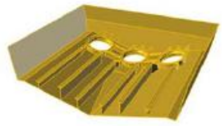
BOAT BUILDING STAGE

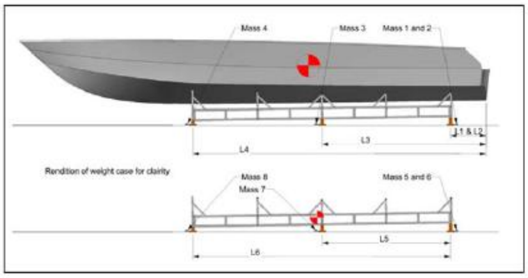
• Structural process advice, installation advice, adaptation and interpretation of rules and guidelines.

BOAT ADAPTATION STAGE

- Follow up scale weighing (up to 110 metric tons)







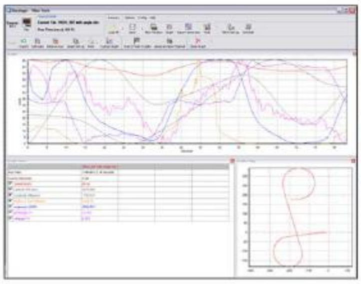
IPS integration process and involvement from Volvo Penta, 3

BOAT VERIFICATION AND/OR ADAPTATION STAGE

- Follow-up: sea-trial with behavior test (rpm, speed, trim, heel, acceleration, consumption) + report, propeller choice!
- Hull and load adaptation/modifications based on test data.
- Re-verification.

$$\alpha = \arctan\left(\frac{v^2}{g \cdot r}\right)$$

v = velocity [m/s]
g = gravitational constant
r = radius of turn



IPS database

The customer database contains >550 brands/yards and many more models. These are customers that have placed their trust with Volvo Penta as a partner in product development.

16mroundbilge	ATMyacht	CoastalCraft	FastCatamaran	Hansheng	Kumamoto	MSSZ	Oyster	Robsonasymetric	Skogenes	Ukraine
1700Powerplay	Aurora	Conam	Ferretti	Hargrave	KustbevakningCobra	Muscat	Pacifica	Rockharbour44	SL650	Ukrainianboat
19_9TFerry	AustraliaYachts	ConcordiaYachting	Fiart	HarmanYachts	LagoonRoyal	Mustang	PalmBeach	Rodman	SmeineYachtcenter	UkrkrotoCiesinski
GradossurYachts	AxisYacht	CoqueBlue	NordicSky	HebeBeatriz	LakeTiticaca	MYSentha	PalmMarine	RogerHillYachtDesignLtd	SOGICA	Ullman-Runnabout45
AbacusMarine	Azimut	CorFisher	FINCAT	Helgyprins	LargecatforIPS	Nasjonel	Passenger15knotPeru	Romano	SogicaOberbridge43	Unathi48
Absolute	Bala	CorsandeSWW	FinnishQuad	HershineMcKinna	LazzaraYachts	NautaYachts	Passengercatfahti	RoyalDenship	Solare48	Unidelta
ACM	Balticworkboats	Cranchi	Fisherysurveillancev.	HFMarine	Leisurecat	Navaldesign_ConsultingSRL	patrol	RoyalTeam	Solemar	Uniesse
Activa	BandD	CrestaMotorYachts	Fishingvessel	Hinckley	LeonDengboat	NavalDynamicsAS	PaulJany	RubiCat	Somi	UPAYachtsN.V.LTD
Adaboatyard	Bantum	CrucerotwinD12800	Fjellstrand	HoekDesign30m	LevefortcomalLTDA	NavalitisEngineeringLtd	PC4606	RupertMarin	SouthBoats	USDOC
Adv.Con.Unl.	BarracudaYachtDesign	CruiseLineYachtBuilders	Fjord	Hood	Linssen399	Navetta22m	Penta60	Rybovich	SoutherlyDesigns	Wake66
Africat	BasileQuad	Cruiser	FjordMolde	Horizon&Vision	Loha	NavyPakistan	PermareYachts	SAFEHAVENMARINE	SoyasianMarine	Valk273
Aguti	Bavaria	Cruisers	FlagMarine	Houseboat	Lolayachts	NavyPeru	peterlowedesign	Saga	Spainprojects2011-03	VallingShipSurvey
AlronMarine	BellaMotoryachts	Cumberland44	Formula	HSB4000	Longisland40	NavytwinD6310hp	Peterscatamaran(HYSU)	Sailfish	Spencer	Wallypower
Albin	Bella	CustomYachts	Fountain	HudsonYachts	Luck	Nekuton	PlanYacht	Sailor34	Spencer64	VanderValk
AlDhaen	Beneteau	Dafeiyang	FountainPajot	HullformIPDrewMcCay	LuthornYachts	Nestek20mtl_Y	Pikilos16	Sakurasima	SpencerYachts	Waycht
AlenYacht	Bestway	DamenShipyard	FourWinns	Humphree70ft	Lynx	NewFolder	PilotboatsUSA	Salthouse	SpiritYachts	WesmacSDK4
AlHarebMarineboat	BladeBoats	DanishYachts	FPBoatsBluize	Hunt36	M14	NewOceanyachts	PioneerMotorYacht	SanJuanYachts	SSF(ShingShengFa)	Wester
Alice	BlueReef55	Daytona	FranchiniYachts	HuntdesignGC538	MSB-Hungary	NewTuna	PioneerBoatSwift	SanLorenzo	StarFisher	VGYacht
Allaisrossignol	BluMartin	DeBirs	Freedom	Icon54	Magnum40	NicolasCasas	PLASCOA	SANTANA	StBarth	WhiteSpirit60
Allegro	BMTNigelGee	DeepVee	FrenchCAT	IdalFinland	MainShip	Nimbus	PolyMarine	Santarpia	StealthYachts	VicemYachts
AlnMaritec	BonusIPS400	Delta	FribergsElectriska	Imax	Manawaki	NISlyachts	PortofinoMarine	SaracatsBrothersSA	Stella	VictaMRoma
Alruban42	BoksaMarineDesign	DennisGarrelCostaRica	FuzhouAllegro	Incheon	Manavi	Noah76	PowercatSquadIPS650	Saratov	Storebro	Viking
Altair	BordoGroup	Designholg	FW76	INI	Mangusta72	NoosaCat	Powerplay	ScandicPolkraft	Stormforce16	VikingMarin
AltamarYachts	Borghegnidesign	DHS	GA40	Innovationcatamarans	MarcoPolo	Nordhavn	Predator	Schaefer	StPetersburgCityGov.	Windcat
AlteraRepower-Altea	Breedendam	DickeyBoats	Gagliotta44	IntechBoating	Mareoro60	NordWest	President	Scirocco50SHUTTLE	Strandcraft38	Windy
Alusafe	BrodemaAA	DonSenior	Galeon	Intermarine	MarineAlutech	Norseman(HaiShengS.B)	PrevezaYachts	Sculley	Stylsfbolagetkat	Wintair
AlX66	C&H	Doral36	GalileoYacht	IslandPilot	Mariner430	NorskAmbulansefly	PrimatistaBrunoAbbate	Scully	Sunbird	Vismara
AmericasCupCats	CantiereNautico	Douamartini	GCGmarine	Isonaval	Maritimo	NorsiCat	PrimaYachts	SeaCraftLLCFerry	Sunnav	Woodenyachtindia
Applause	Carbrasmar	DP(DallaPiet....Yachts)	Genesis	JadeYachts	MarlowYachts	NOSProvider	Primorets	SealifeDesign	Sunquest	Voyager
Aprealitare	CardellMYXD	Dragon	GeorgNissen	Japan3xIPS	Marquis	NT411	Princess	Sealine	Sunseeker	VPtripleIPS600
Aquilium	CarenaSerapo	DubaiMarine	GinoGandino	Javelin42	Marumana	Numarine	Prinz	Seamaster	SwedeShip	XIAMENHANSHENGYT
Aramis35	Carribean	DutchYachting	GlobalYachtBuilder(GYB)	J-craft	MasterMarine	OD-marine	PrivateerYachts	Seascout	SwedishShipMarine	XingYang
Arasur	Carver	DynaCraft	GobbiAtlantis	Jeanneau	MaverickSFY	Ocean5	Project316	Seatrials-NZIPSBoats	TaChou	Xsea
ArcadiaYachts	Cat11	Dynasty	Grand	JeffersonYachts	MauiYachts	OceanAlexander	ProShip	Seavee	TansaMarine	Yamaha
Arcticblue35	Cat13	EAC	GrandBanks	Johnssonyachts	MaxiDolphin	Oceania	QuattroMarine	SEGUEYACHTS	Targa	YasudaShipyard
AresaGroup	Catamaran-Austria	Egawa	GrandHarbour	Joyce	Maximum	Oceanmarine	RafaelMSN	Selgia24mCat	Tecnomar	Youanna60
Argohydrofoil	CatamaranSouth	Egemar	Greenline33	JSCPrimorets	MBLSupply	Oceantouring	Raidco	Seigur	Tenderboat	YukayYachts
Aria	CatamaranTecnao	Elan48	GreklandIPS2	JVC	McKinna78	OdeMannefeldt	RailCat	SemiplaningdinAustria	Tiara	Y/Vene
Arista	Cayman	Elan48	GSMarineProduksjon	Kamamarine	MDYacht	OktaShipyard	Realpowerboats	Senatorboats	TransWorld	Zahra19
Arkona	CBMYachts	Elite15m	GulfCraftInc	KBMSARH01	Med45	OlaL-O	Rebelmarine	SESEuropeAB	TreStar	ZeelanderYachts
Armada	CCE	Endeavour42	GustoYachtsGriffin	KBV312T2	MediacoYachts	Oliver	ReconBoats	Sessamarine	Tresco	Zenit
Armada	Ceelen&Bekker	EngelDesign	GuyCoachPilot	KelseyLee	Melian	Olympia	ReconCat43	SevenSeas	Trestford	
Armortechniques	CH50	EnterpriseMarine	HadramiMarine	KhaShing	Meriytind	OrientalBoats	Revival	SFM25mWPC	Tricon_SEINISI	
Arpaspilotboat	Chapparal	ErsinDenizcilik	HaiShengShipBuilding	Kiwifantastic	Menorquin	Orsis	Riostar	ShannonEiler43	Trident	
AskeladdenmedZeus	Choisi	ETOU-DY	Hallocat34	KLASEA	MikelsonYacht	OrubogluSistem	Riva38	Sharpyachts	Tristan56	
ASTILLEROMARVO	ChrisCraft	Evolutionyacht	Hamaishi-kosensyo	Kockums	Millenium	OSK-ShiptechAS	Riviera	Shark50Pupayat	TullioAbbate	
AstillerosdeAlicante	Cimitarra	ExtremeRibs	HamptonYachts	Kone45	MoaTecnica	Osprey	RivieraYachtsArg	Sibiriplotboat	Tunafishboat	
Astinor	Cleopatra	Faeton	HangLik	Koreannavyboat	Montebello	Otam	Rivolta66	Silkline	Typhoon37Holland	
Astondoa	Clintsboat	Fairline	Hanko-PolarDiesel	KrogenExpress	Morgan	Ovation62	RKyachts	SirenaYachts	Virgo	
Atlantis	CMS	Fast	Hanse-Fjord	KSS	MoulderBellagioVriask	Oxta2000	RobertoHolzhacker	Skila	UFO119	