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- ROV for Deep Sea Operation

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Investigation on Effect of Variation in Compression Ratio on Performance and Combustion Characteristics of C.I Engine Fuelled With Palm Oil Methyl Ester (POME) and Its Blends By Simulation

By Sanjay Patil
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Abstract - The paper describes the development of zero dimensional single zone thermodynamic model for compression ignition engine cycle simulation. Rate of heat release due to combustion is modeled with double wiebe function, takes care of premixed as well as diffusive phase of combustion. Adjustable parameters of wiebe function are obtained by fitting it to experimental mass fraction burned profile by least square method. Empirical correlations are established between adjustable parameters of wiebe function, relative air-fuel ratio and engine operating conditions. The simulation is used to analyze the engine performance fuelled with diesel, Palm Oil Methyl Ester (POME) and its blends. Effect of change in compression ratio on peak pressure, net heat release rate and brake thermal efficiency is analyzed and discussed. The model is validated by comparing predicted peak pressure and brake thermal efficiency with diesel and POME –diesel blends at 17.5:1 compression ratio with that of experimental results.

Keywords : Biodiesel, compression ignition engine, double vibe function, simulation.

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INVESTIGATIONONEFFECTOFVARIATIONINCOMPRESSIONRATIOONPERFORMANCEANDCOMBUSTIONCHARACTERISTICSOFC.IENGINEFUELLEDWITHPALMOILMETHYLESTERPOMEANDITSBLENDSBYSIMULATION

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I. Introduction

Energy is prominent requirement of present society. Internal combustion engines have been the prime movers for generating power for various applications for more than a century [1]. The increasing demand, depletion and price of the petroleum prompted extensive research worldwide on alternative energy sources for internal combustion engines. Use of straight vegetable oils in compression ignition engine for long term deteriorates the engine performance and is mainly because of higher viscosity [2-6]. The best way to use vegetable oils as fuel in compression ignition engines is to convert it into biodiesel [7]. Biodiesels such as rape seed, soybean, sunflower and Jatropha, etc. are popular substitutes for diesel [8]. In the present energy scenario efforts are being focused on use of bio diesel in compression ignition engine, but there are many issues related to performance and emission [8]. The optimum operating parameters can be determined using experimental techniques but experimental procedure will be time consuming and expensive [9]. Computer simulation [10] serves as a tool for a better understanding of the variables involved and also helps in optimizing the engine design for a particular application thereby reducing cost and time. The simulation approach allows examining the effects of various parameters and reduces the need for complex experimental analysis of the engine [11]. A validated simulation model could be a very useful tool to study engines running with new type of fuels.

A zero-dimensional single-zone model as compared with multi-zone models is much simpler, quicker and easier to run. [12, 13] and it is capable of predicting engine performance and fuel economy accurately with a high computational efficiency [14]. Hence a zero-dimensional single-zone model is developed similar to the one developed previously by the authors [15] where single Wiebe function is used. In this paper double Wiebe function is used to model heat release rate.

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II. Description Of Mathematical Modeling

a) List of symbols

r = compression ratio.

L = length of connecting rod (mm).

B = bore diameter (mm).

V_{disp} = displacement volume (m^3).

θ = angular displacement in degrees with respect to bottom dead center (BDC).

θ_s = crank angle at the start of combustion.

γ = specific heat ratio.

P = pressure (bar).

V = volume (m^3).

m_c = number of moles of carbon in one mole of fuel.

m_h = number of moles of hydrogen in one mole of fuel.

m_o = number of moles of oxygen in one mole of fuel.

m = mass of the charge (kg).

h_c = coefficient of heat transfer due to convection (W/m^2.K).

A = interior surface area of cylinder (m^2).

T = instantaneous gas temperature (Kelvin).

T_w = cylinder wall temperature (Kelvin).

R = universal gas constant (kJ/kmole.kelvin).

C_m = piston mean speed (m/s).

U = internal energy.

H = enthalpy.

C_P = specific heat at constant pressure (kJ/kg.kelvin).

C_V = specific heat at constant volume (kJ/kg.kelvin).

$\Delta\theta$ = combustion duration in crank angle (degrees).

Q_r = heat released per cycle (kJ).

$\frac{dQ_r}{d\theta}$ = rate of heat released during combustion (kJ/degree CA).

$\frac{dQ_h}{d\theta}$ = rate of heat transfer (kJ/degree CA).

$\frac{dw}{d\theta}$ = rate of work done.

$\frac{du}{d\theta}$ = rate of change of internal energy.

$\frac{dV}{d\theta}$ = incremental change in cylinder volume (m^3/degree CA).

$\frac{dT}{d\theta}$ = rate of temperature change (Kelvin / degree CA).

Q_p = heat released during premixed phase (kJ).

Q_d = heat released during diffusive phase (kJ).

m_p = shape factor of premixed phase.

m_d = shape factor of diffusive phase.

θ_p = burning duration of premixed phase.

θ_d = combustion duration.

b) Energy balance equation

According to the first law of thermodynamics, the energy balance equation for the closed cycle is

$$m\frac{du}{d\theta} = \frac{dQ_r}{d\theta} - \frac{dw}{d\theta} \tag{1}$$

The heat term (rate of heat release) can be split into the heat released due to combustion of the fuel and the heat transfer that occurs to the cylinder walls or from the cylinder walls to gases. The equation (1) can be written as

$$m\frac{du}{d\theta} = \frac{dQ_r}{d\theta} - \frac{dQ_h}{d\theta} - \frac{dw}{d\theta} \tag{2}$$

Replacing the work transfer by $p\frac{dV}{d\theta}$ or by the ideal gas law $PV = mRT\frac{dV}{d\theta}$, rate of heat transfer by $h_c = A(T - T_w)$ and the internal energy can be related to specific heat through the relationship $\frac{du}{d\theta} = C_V\frac{dT}{d\theta}$

Upon simplification we get equation (2) as

$$\frac{dT}{d\theta} = \frac{1}{mC_V}\frac{dQ_r}{d\theta} - \frac{h_c A(T - Tw)}{mC_V} - \frac{RT}{C_V V}\frac{dV}{d\theta} \tag{3}$$

Solving above equation by Range-kutta fourth order algorithm, the temperature at various crank angles during combustion can be calculated.

c) Cylinder volume at any crank angle

The slider crank angle formula is used to find the cylinder volume at any crank angle [10]

$$V(\theta) = V_{disp}\left[\frac{r}{r-1} - \frac{1-\cos\theta}{2} + \frac{1}{2}\sqrt{\left(2\frac{L}{S}\right)^2 - \sin^2\theta}\right] \tag{4}$$

d) Compression and Expansion strokes

The compression stroke starts from the moment the inlet valve closes (IVC) to the moment the fuel injection starts. The expansion stroke starts from the moment combustion ends to the moment the exhaust valve opens (EVO).During these processes the temperature and pressure at each step are calculated using ideal gas equation and an isentropic process [15].

e) Combustion Process

$$\frac{dQ_r}{d\theta} = 6.908\frac{Q_p}{\theta_p}m_p\left(\frac{\theta}{\theta_p}\right)^{m_p-1}\exp\left[-6.908\left(\frac{\theta}{\theta_p}\right)^{m_p}\right] + 6.908\frac{Q_d}{\theta_d}m_d\left(\frac{\theta}{\theta_d}\right)^{m_d-1}\exp\left[-6.908\left(\frac{\theta}{\theta_d}\right)^{m_d}\right] \tag{5}$$

The parameters θ_p and θ_d represent the duration of the premixed and diffusion combustion phases. Also, Q_p and Q_d represent the integrated energy release for premixed and diffusion phases respectively. Shape factors m_p and m_d for premixed and diffuse phase of combustion have to be such that the simulated heat release profile matches closely with experimental data. These shape factors are obtained by fitting wiebe function to experimental mass fraction burned profile using least square method. Prior knowledge of actual overall equivalence ratio is necessary because the fuel/air equivalence ratio depends on the amount of fuel injected inside the cylinder, from which the mass of fuel admitted can be calculated [18]. The amount of heat released in premixed mode is 40% of the total heat released per cycle is assumed.

f) Heat transfer

The convective heat transfer between gases and cylinder wall is considerable and hence it directly affects the engine performance. The convection heat transfer in kJ/degree crank angle is given by

$$\frac{dQ_h}{d\theta} = h_c A(T - T_w) \tag{11}$$

Where Heat transfer coefficient due to convection (h_c) is given by Hohenberg equation [19].

$$h_c = \frac{130 P^{0.8} (C_m + 1.48)^{0.8}}{V^{0.06} T^{0.4}} \tag{12}$$

g) Ignition delay

An empirical formula, developed by Hardenberg and Hase [20] is used for predicting Ignition delay in crank angle degrees.

$$ID = (0.36 + 0.22 C_m) \exp\left[E_A \left(\frac{1}{RT} - \frac{1}{17{,}190} \right) \left(\frac{21.2}{P - 12.4} \right)^{0.63} \right] \tag{13}$$

Where ID = ignition delay period.
E_A is apparent activation energy

h) Gas properties calculation

A hydrocarbon fuel can be represented by $C_x H_y O_z$. The required amount of oxygen Y_{cc} for combustion per mole of fuel is given by:

$$Y_{cc} = m_c + 0.25 m_h - 0.5 m_o \tag{14}$$

The minimum amount of oxygen required $(Y_{\min})$ for combustion per mole of fuel is

$$Y_{\min} = Y_{cc} - 0.5 m_c$$

The gaseous mixture properties like internal energy (U), enthalpy (H) specific heats at constant pressure (C_P) and constant volume (c_v) depend on the chemical composition of the reactant mixture, pressure, temperature and combustion process and can be calculated using following equations.

$$U(T) = A + (B - R) * T + C * \ln(T) \tag{15}$$

$$H(T) = A + B * T + C * \ln(T) \tag{16}$$

$$C_p(T) = B + \frac{C}{T} \tag{17}$$

$$C_V(T) = (B - R) + \frac{C}{T} \tag{18}$$

Here A, B and C are the coefficients of the polynomial equation.

i) Friction losses

Total friction loss calculated by the equation [21].

$$FP = C + 1.44 \frac{C_m * 1000}{B} + 0.4 (C_m)^2 \tag{19}$$

Where *FP* is total friction power loss and *C* is a constant, which depends on the engine type, C = 75 kPa for direct injection engine.

III. Methodology

a) Simulation

A thermodynamic model based on the First law of thermodynamics has been developed. The molecular formula of diesel fuel is taken as $C_{10}H_{22}$ and biodiesel is approximated as $C_{19}H_{34}O_2$. A computer program has been developed using MATLAB software for numerical solution of the equations used in the thermodynamic model described in Section 2. This computes pressure, temperature, brake thermal efficiency, brake specific fuel consumption and net heat release rate etc, for the fuels considered for analysis. Fuels considered for analysis are namely B20, B60, and B100, 20%, 60%, and 100% POME with petroleum diesel respectively.

b) Experimental

A stationary single cylinder, 4 stroke, water cooled diesel engine developing 5.2 KW at 1500 rpm is used for investigation. The technical specifications of the engine are given in Table 1. The fuel properties are determined using standard procedure and tabulated in table 2. The cylinder pressure data is recorded by using piezoelectric transducer for 80 cycles. The average of data for 80 cycles is computed to evaluate mass fraction burned profile and combustion duration within the framework of first law of thermodynamics.

Table 1 : Specifications of Engine

Sl.No	Parameter	Specification
1	Type	Four stroke direct injection single cylinder diesel engine
2	Software used	Engine soft
3	Injector opening pressure	200 bar
4	Rated power	5.2 KW @1500 rpm
5	Cylinder diameter	87.5 mm
6	Stroke	110 mm
7	Compression ratio	17.5:1
8	Injection timing	23 degree before TDC

Table 2 : Properties of Diesel and POME

Properties	Diesel(B0)	POME(B100)
Viscosity in cst(at 30°C)	4.25	4.7
Flash point(°C)	79	190
Fire point(°C)	85	210
Carbon residue (%)	0.1	0.64
Calorific value(kj/kg)	42700	36000
Specific gravity(at 25°C)	0.830	0.880

IV. Results And Discussion

a) Effect of compression ratio on

i. Peak pressure

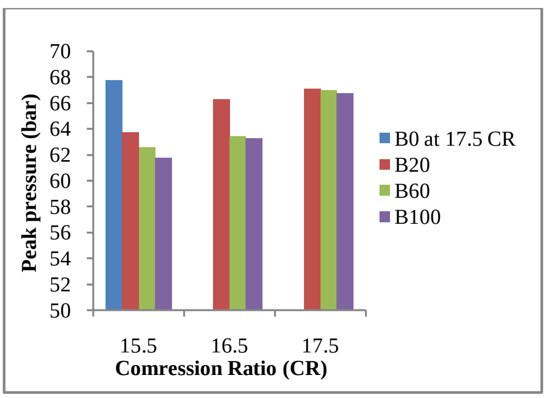

Figure 1 : Variation of Peak pressure with test fuels

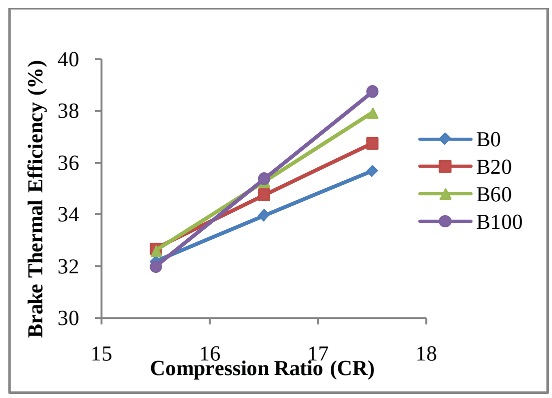

Figure 2 : Variation of Brake thermal efficiency at different Compression Ratio with test fuels at different Compression Ratio

Figure 1. shows the variation of peak pressure with various test fuels at different compression ratios. With increase in compression ratio, the peak pressure is increased for all test fuels. At every compression ratio, the peak pressure decreases with increase in proportion of biodiesel in the blend and also found that the peak pressures of all test fuels are less in comparison with that of diesel.

Increase in compression ratio enhances the pressure and temperature of air–fuel mixture in compression stroke results in increased peak pressure. Increase in proportion of biodiesel in blend burns more fuel during diffusion phase of combustion and lower calorific value of blend causes in decrease of peak pressure.

ii. Brake thermal efficiency

Figure 2. Shows the variation of brake thermal efficiency for various test fuels at different compression ratios. It is observed that brake thermal efficiency for all the test fuel is increased with increase in compression ratio. From the results it is also observed that the brake thermal efficiency at every compression ratio is increased with increase in proportion of biodiesel in the blend. This is due to the presence of oxygen molecule in the biodiesel which enhances combustion phenomenon. The brake thermal efficiency of test fuels is lower at compression ratio of 15.5:1 and 16.5:1 and higher at compression ratio of 17.5:1 in comparison with

iii. *Net Heat Release Rate*

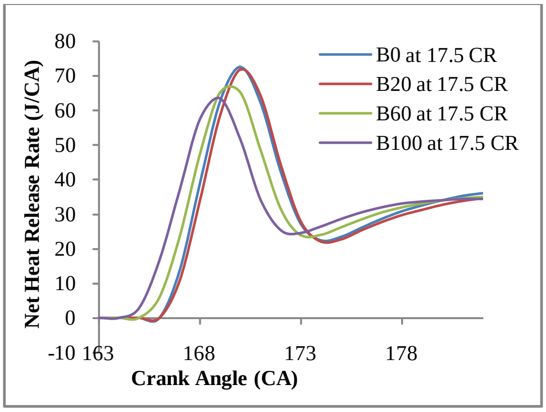

Figure 3 (i) : Variation of Net heat release rate with test fuels at 17.5 Compression Ratio

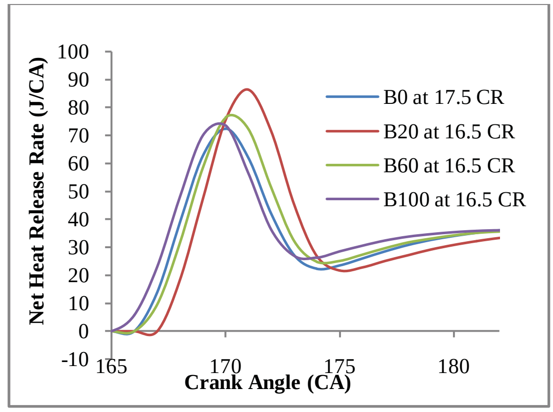

Figure 3 (ii) : Variation of Net heat release rate with test fuels at 16.5 Compression Ratio

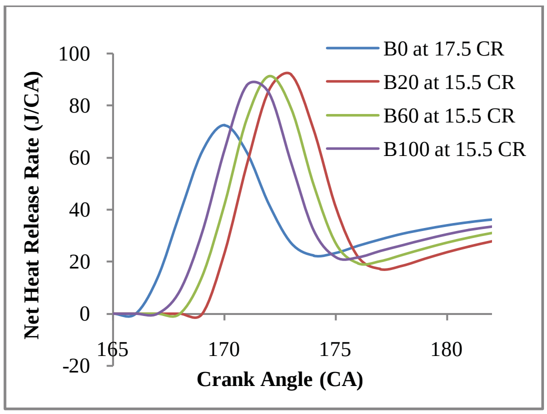

Figure 3 (iii) : Variation of Net heat release rate with test fuels at 15.5 Compression Ratio

Figures 3(i. ii & iii). Shows the variation of net heat release rate for various test fuels at different compression ratios. From the results it is observed that decrease in compression ratio increases heat release in premixed phase; however occurrence of maximum heat release moved away from TDC. This is because decrease in compression ratio increases the ignition delay period, which causes more fuel to burn late in the expansion stroke. Same trend is observed for all the test fuels. Increase in proportion of biodiesel increases the cetane number of blend, decreasing the delay period. Decrease in delay period burns less amount of fuel in premixed phase, hence decrease in net heat release rate is observed at every compression ratio.

b) *Effect of load on*

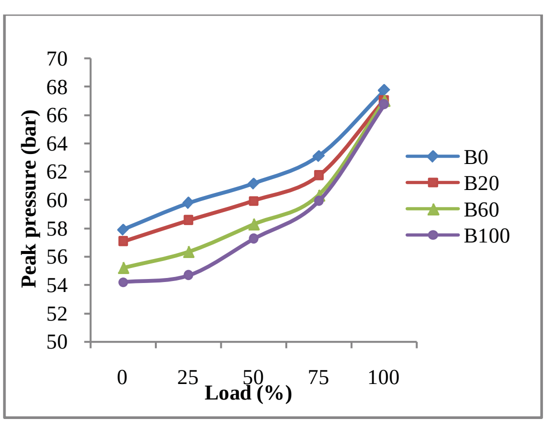

Figure 4 : Variation of Peak pressure with test fuels at different load

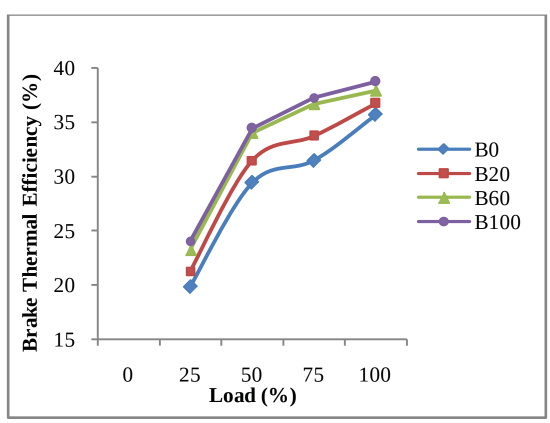

Figure 5 : Variation of Brake thermal efficiency with test fuels at different load

Figures 4 & 5.Shows the Variation of peak pressure and brake thermal efficiency with test fuels at different load. From the predicted results it is observed that increase in load increases the peak pressure and brake thermal efficiency. Same trend has been observed with all test fuels.

V. Model Validation

With the help of developed model theoretical results are predicted for brake thermal efficiency and peak pressure for all test fuels. The same are compared with that of experimental results. The figures below highlight the features. Predicted brake thermal efficiency and peak pressure at full load when engine is fuelled with B0, B20, B60 and B100 are compared with experimental results are found in closer approximation.

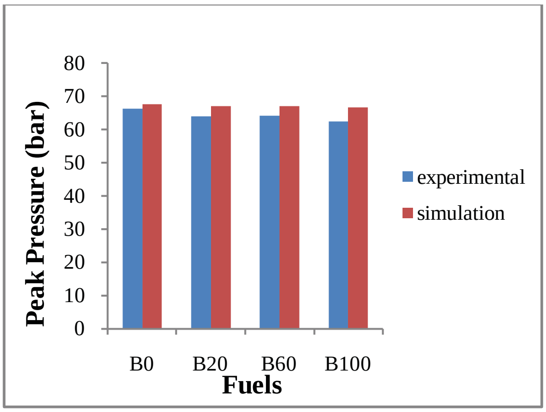

Figure 6 : Peak Pressure at full load

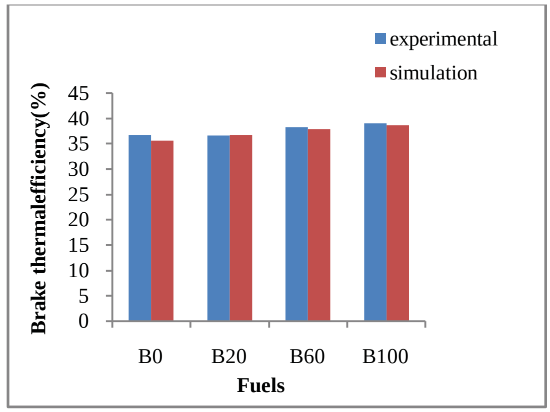

Figure 7 : Brake thermal efficiency at full load

VI. Conclusions

The thermodynamic model developed is used for analyzing the performance characteristics of the compression ignition engine. The modeling results showed that, with increase in compression ratio peak pressure and brake thermal efficiency are increased for all test fuels. At every compression ratio, increase in proportion of biodiesel in the blend decreased peak pressure and increased brake thermal efficiency. This model predicted the engine performance characteristics in closer approximation to that of experimental results. Hence, it is concluded that this model can be used for the prediction of the performance characteristics of the compression ignition engine fueled by any type of hydrocarbon fuel.

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Development of Front End Crash Structure for Lightweight Hybrid Electric Vehicle

By J. Christensen, C. Bastien, M. V. Blundell & N. Ravenhall
Coventry University

Abstract - Rooted in the £29 million Low Carbon Vehicle Technology Project (LCVTP), Coventry University has continued to conduct research into lightweight Body In White (BIW) design and lightweight crash structure development utilising structural optimisation for alternatively fuelled vehicles such as Hybrid Electric Vehicles (HEV). This paper explains how a lightweight HEV front end crash structure has been developed, refined and validated using numerical analysis. This is based on structural optimisation results, benchmarking of similar sized vehicles and previous experience of crash structure development.

Keywords : Body In White (BIW); Topology optimisation; Crashworthiness; Lightweight Hybrid Electric Vehicle (HEV); NCAP; NHTSA.

GJRE-B Classification : FOR Code : 090205

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Development of Front End Crash Structure for Lightweight Hybrid Electric Vehicle

J. Christensen [α], C. Bastien [σ], M. V. Blundell [ρ] & N. Ravenhall [Ѡ]

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I. Introduction

This paper will be concerned with presenting and discussing the development of a front end crash structure for a lightweight Hybrid Electrical Vehicle (HEV). This will be based on topology optimisation results, which has been published and discussed in Bastien (2010), Bastien and Christensen (2011), Christensen et. al. (2011), Christensen et. al. (2011a), Christensen et. al. (2012), Christensen et. al. (2012a), Christensen et. al (2012b) and Christensen et. al. (2012c). The following section will briefly summarise the findings in the listed papers, which have formed the starting point for this paper.

a) Topology optimisation study

The structural loadpaths to be used for the Body In White (BIW) and the crash structures were extracted from an initial design volume, i.e. Computer Aided Design (CAD) model, by employing Finite Element (FE) based linear static topology optimisation and New Car Assessment Program (NCAP) representative loading. Figure 1 illustrates the design volume used for the topology optimisation study which will be utilised as a reference point to summarise the topology optimisation throughout this section.

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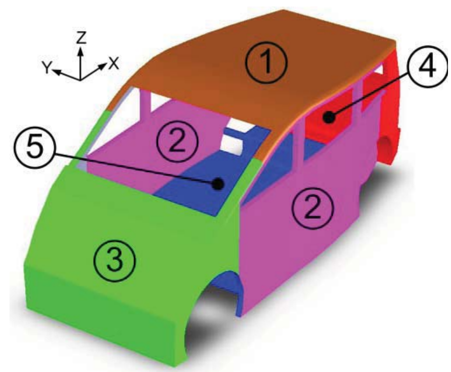

Figure 1 : Design volume

The results of the topology optimisation study is illustrated by Figure 2.

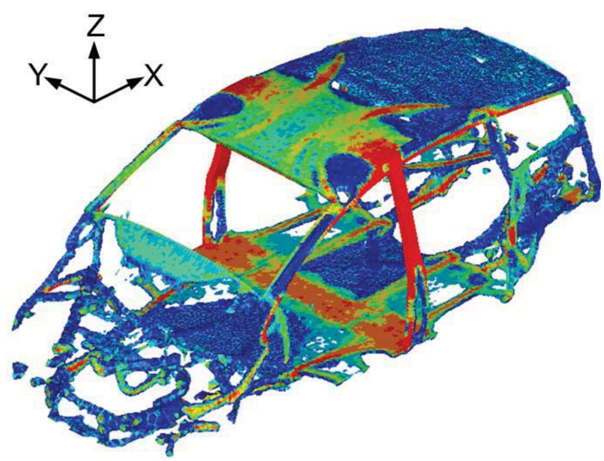

Figure 2 : Example of topology optimisation result

The results of the topology optimisation revealed that the floor area, i.e. "5" in Figure 1, was subject to distinguishable changes, primarily as a function of the structural integrity of other components such as a battery pack, Christensen et. al (2011).

In addition, the generalised topology of the roof area ("1" in Figure 1) remained consistent throughout the entire study. The simple conclusion was that the topology of this area had converged. The converged roof topology was unconventional when compared to the roof bow structures of many modern day passenger vehicles, Christensen et. al. (2011). There were however some concerns with respect to the structures ability to

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withstand the loads associated with a vehicle rollover, Christensen et. al. (2012) and Christensen et. al. (2012c).

Finally, the side area topology did, in line with the roof topology, also remain consistent, yet, a significant number of the models displayed a rather vague definition of the side area topology.

The results relating to the roof, floor and partially the side area topologies, which in essence make up the "safety cage" of the vehicle generally display relatively well defined loadpaths.

Thereby, the individual model topologies (of the safety cage) were found to be viable solutions which can be implemented in the BIW design in order to successfully withstand the dynamic crash loading scenarios. Nevertheless, this is solely based upon mechanical engineering judgements and is not at this point backed up by any calculations.

The above thus suggests that even though the "correct" method of representing the crash scenarios includes explicit (dynamic) modelling, useful results (load path extraction) can be obtained by utilising relatively simplistic linear static topology optimisation.

The key benefit of this approach was the low CPU cost, a typical calculation time of one topology optimisation model, was approximately 45 minutes, using 2 cores.

When the focus of attention was shifted to the front and rear area topologies ("3" and "4" in Figure 2) significant changes due to variations of force application angles and stiffness values were found, Christensen et. al. (2011).

The response of the topology optimisation seemed to be “triangulation”, i.e. the widespread use of triangles within the geometry, i.e. design space. This made perfect sense from a linear static point of view, as the stiffest geometry in solid mechanics is a triangle. However, this raises serious concerns when the subsequent step is taken into dynamic loading, primarily because of the triangles resistance to buckling, which undoubtedly will have a negative influence on the crushability, and therefore the dynamic crash performance of these very vital areas, more specifically design of the crumple zone.

This is evidently one of the major limitations of the linear static (implicit) solver and highlights the necessity for further steps in the development of topology optimisation algorithms, particularly with an emphasis on non-linear material behaviour.

The extend of this limitation will be further highlighted and analysed during the remaining sections of this paper.

With the brief summation of the topology optimisation complete, the focus of attention will now be aimed at developing the front crash structure of the vehicle using shape and size optimisation, with the basic loadpath definitions defined by the topology optimisation.

II. Front Crash Structure Benchmarking

The development of the front end crash structure commenced with a benchmarking vehicles of similar size (external dimensions) and mass in order to define the performance requirements for the front crash structure.

a) NCAP HEV Target setting

The aim of this task was to define a target setting for the HEV front crash structure, in order to meet a 35mph rigid barrier impact (56.65km/h nominal) NHTSA (2012).

In order to do so, the first step of this study was to investigate the current state of art in vehicle’s structural performance and understand how an "ideal" crash pulse could be obtained for a lightweight HEV.

Five vehicles were initially chosen for this study, primarily due to their structural layout and associated crash performance, courtesy of NHTSA testing, NHTSA (2011). The relevant data for the five chosen vehicles is listed in Table 1.

Table 1 : NHTSA test results, NHTSA (2011)

Vehicle	Model year	Test mass (kg)	Impact speed (km/h)	NHTSA test number	Post impact max. crush (mm)
Ford Fiesta	2011	1359	56.5	6996	612
Mini Cooper	2008	1371	56.3	6291	398
Smart FourTwo	2008	1057	55.9	6332	320
Jaguar Xtype	2003	1777	55.7	4484	413
Honda S2000	2003	1465	57.0	4462	545

The layouts of the five chosen vehicles are listed below:

1. 2011 Ford Fiesta: Front transversely mounted engine, front wheel drive, 5 seats.
2. 2008 Mini Cooper: Front transversely mounted engine, front wheel drive, 4 seats, short front overhang.
3. 2004 Smart FourTwo: Rear transversely mounted engine, rear wheel drive, 2 seats, very short front overhang.
4. 2003 Jaguar X type: Front transversely mounted engine, four wheel drive, 4 seats, long front overhang.
5. 2004 Honda S2000: Front longitudinal mounted engine, rear wheel drive, 2 seats, long front overhang, no roof load path.

In addition to the above justification of the selection of vehicles for comparison, a further justification can be made based on the above vehicle layouts. The first 3 (Fiesta, Cooper and FourTwo) are similarly sized to the proposed structure of this paper (external dimensions and mass values), whereas the Jaguar and the Honda were chosen in order to better understand the effects of a long front overhang.

Due to publishing restrictions only the Ford Fiesta will be presented in greater detail below.

The data available from the above NHTSA test reports, NHTSA (2011) were mainly focused on occupant injuries, with considerably less data available on the actual structural performance of the vehicles in question. In general, the Vehicle Acceleration Pulse (VAP) may be considered as an ‘enabler’ for reducing the severity of the occupant injuries, i.e. reducing VAP leads to a reduction in severity of occupant injuries. Other factors such as the restraint system does however also significantly influence the severity of occupant injuries. Due to the nature of the overall study, the VAP was nevertheless considered in isolation.

b) 2011 Ford Fiesta

The Ford Fiesta was the newest model year vehicle under investigation, and was one of the highest rated small vehicles tested by the Insurance Institute of Highway Safety (IIHS), IIHS (2012), offering a good performance benchmark target for the new vehicle design.

Newton's second law of motion was used to extract the VAP, equation (5), assuming that all the vehicles' mass remain coupled during the crash scenario.

$$VAP = \frac{F}{m} \tag{1}$$

In equation (1), 'F' is the force exerted on the vehicle (from the barrier), this was extracted from the NHTSA data NHTSA (2011), and 'm' is the vehicle test mass available from Table 1. Thereby the pulse can be obtained, Figure 3 represents the resulting VAP for the FORD Fiesta test.

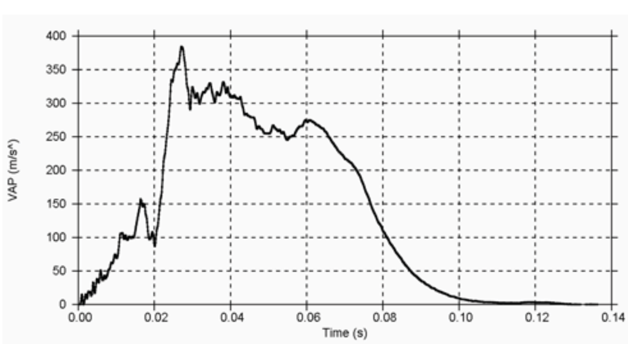

Figure 3 : NHTSA crash pulse of 2011 Ford Fiesta

The following discussions and conclusions are all based on Figure 3, the NHTSA test reports, data and videos all available from NHTSA (2011).

The first (local) VAP peak of approximately 15g (g = 9.82 m/s^2) occurs at 18ms, this was caused by the initiation of the crush can. The highest VAP peak occurs at approximately 28ms, and was caused by the engine contacting the rigid wall. Between 30ms and 60ms, the main longitudinals (longits) collapsed, as well as the engine ancillary bay, giving rise to a relatively "horizontal" profile of the VAP. Around 60ms the wheel made contact with the sill, leading to a local increase in VAP, ultimately followed by the vehicle ride down.

From the test videos, NHTSA (2011), it was noticeable that the plastic deformation, i.e. structural damage was very much localised at the extreme front of the vehicle, with no visible deformation of doors or door apertures. This was collaborated by the test report, as no change in door aperture pre to post test was measured, and only 2mm difference in seat mounting positions were measured. This fact was consistent with the approach of using linear static topology optimisation, for the development of the passenger cell, as originally assumed.

The approach of the above analysis was also adopted for the remaining four vehicles listed above. As previously mentioned, these will however not be further addressed in this paper.

c) Summary of NHTSA results

Figure 4 illustrates the overlay of the VAP for the five chosen vehicles.

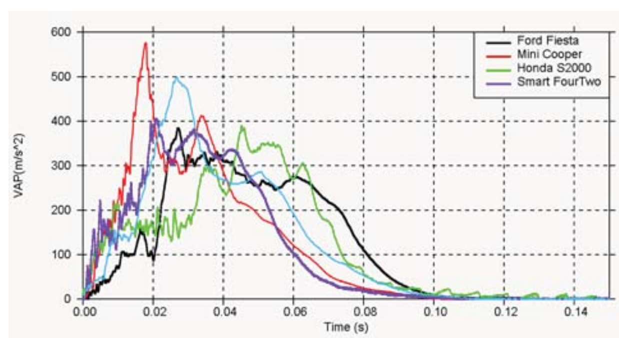

Figure 1 : Acceleration pulse overlay of the 5 vehicles

As Figure 4 reveals, the VAP varies significantly between the 5 vehicles.

Table 2 : Summary of the 5 vehicle's structural performance

Vehicle	Impact duration (ms)	Acceleration g (m/s^2)		Intrusion (mm)
		Max.	Ave.	
Ford Fiesta	100	39.4	16.0	612
Mini Cooper	90	58.6	17.7	398

Smart FourTwo	80	41.8	19.8	320
Jaguar X-Type	90	51.0	17.5	413
Honda S2000	110	39.8	14.0	545

The average vehicle acceleration was calculated by taking the total impact energy, defined as the integral of the contact force of test vehicle against the rigid wall and the vehicle motion, divided by the maximum intrusion.

d) Global Acceleration pulse target setting

It can be seen from the vehicles investigated, they are developed for several load cases. For a realistic front concept structure to be created from this investigation, both low and high-speed frontal impacts will be considered. No stiffness or NVH load cases will be assessed, nevertheless the structure will be developed with these load cases also in mind. The front end was developed to create a global vehicle pulse which will work for both impact load cases, with the targets outlined below.

Front Low Speed (FLS) damageability a.k.a. "Thatcham insurance rating" tests have recently been adapted to better represent real world crash scenarios related to insurance clams. The FLS load case therefore consists of a frontal impact at 15kph, with a 40% offset barrier, applied at an angle of 10° relative to the x-axis in Figure 1 and Figure 2.

This assess the cost of repair of the full vehicle, in which major structural damage is a significant concern, as repair costs (and thus vehicle insurance category) will be high. Consequently the parameter for the FLS scenario is no visible longit deformations. This can be quantified by setting a limit of all plastic strain to a maximum value of 2%, suggesting all damage is localised to the bumper beam and crush cans.

The high-speed frontal 35mph (FHS) for this concept structure is in essence the NCAP test, as previously discussed. This is of course based on occupant injury, however as seen in the tests the average accelerations are similar between all vehicles. the target, idealised global pulse shape metrics can therefore be visualised for the concept front end, as shown in Figure 5.

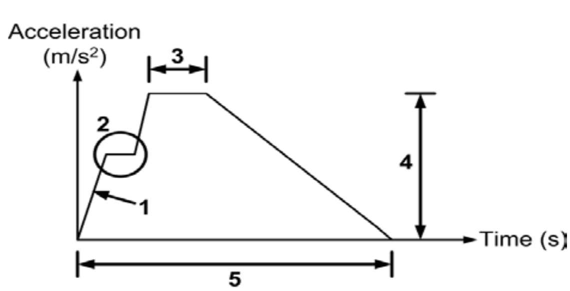

Figure 5 : Idealised global pulse profile

The idealised pulse profile illustrated in Figure 5 is based on the following ideologies:

1. **Low speed damageability control.** Using replaceable crush cans to absorb a specific amount of energy, equal to the FLS low speed Thatcham insurance rating test. The crush cans should be as stiff as possible, in order to ramp up acceleration as rapidly fast as possible without damaging the longitudinals.
2. **The acceleration should rapidly ramp up**, in order to engage the occupant(s) in the restraint system early on. Thereby the occupants(s) acceleration will be coupled to the vehicle acceleration thereby minimising any lag between the two offering increased control.
3. **Acceleration peak duration.** This should be kept at short as possible whilst maintaining the pulse shape, i.e. not bottoming out the crush space prior to all impact energy being absorbed.
4. **The peak acceleration** should not to exceed 42g. This is the maximum value found during the benchmark study. In addition, this value is well below the 80g legal requirement.
5. **The crash duration should be as long as possible, in order to** reduce the average accelerations as much as possible. This can be obtained by using at least 400mm of the available crush space in the front end of the vehicle, based on the target setting.

Lack of front end ancillaries simplifies the development of this pulse shape, as the interaction of the engine to the crash structure has less effect at the front end of the vehicle. The front-end stiffness will be dominated by the controlled crush of the main longitudinal members, and their interaction with the adjacent structure. The lack of front end ancillaries will however also affect the stiffness requirements of the occupant safety cell.

The crash investigations also showed that bulkhead intrusions are very small for most vehicles, again ensuring the deceleration distances for the occupants are maintained. This is a key target for the design and prediction restraint systems performance, and reduction of occupant injury. It can be assumed that this concept vehicle will be designed with a very stiff bulkhead with this in mind, so only the structure forward of the front bulkhead was be considered in the subsequent analyses.

III. Development of HEV Crash Structure

To create a front-end structure suitable for crash events, the data and information gathered from previous section has been be used to create the targets for the structural performance, as previously discussed.

Spring mass damper modelling was envisaged as a possible concept-modelling tool, however, further investigation showed this modelling technique is mainly based on empirical test data of known sections / stiffness. With none of this data available to initially set up a 1D spring damper model, AISI (2012), 3D Finite element non-linear analysis will be used throughout to develop a front end design, using the industry standard solver code LS-Dyna.

To develop a suitable front end structure further research into structural deformation modes for crash energy management for very short front end vehicles was required, in addition to material investigations. This aimed to improve the structural efficiency of the design, whilst ensuring the viability in terms of manufacturing volume and methodology.

a) Additional benchmarking

The 5 vehicles investigated previously gave a lot of insight in to the mechanics of a crash event, however only the Smart is of real relevance in terms of BIW architecture. To further progress this project, it was deemed necessary to further investigate the forward structures of more modern vehicles with very short front ends.

To do this, the Peugeot 107 / Citroen C1 platform, Toyota IQ and Audi A2 were analysed. The Peugeot and Toyota utilises a "conventional" steel construction whilst the Audi A2 utilises an aluminium space frame.

b) Initial Concept

Based on the topology optimisation results, the interpretation thereof, previous crash design knowledge, ideas generated from the above benchmarking and crash analysis investigations, the primary loadpaths for the front end crash structure was defined as illustrated by Figure 6.

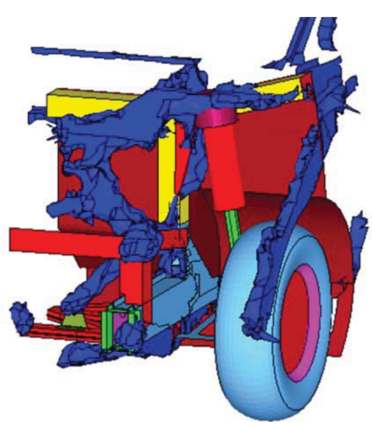

Figure 6 : Crash structure definition based on topology optimisation

Subsequently shape and size optimisation was used to extract initial values / estimations of the cross-sectional properties including gauge thicknesses', Christensen et. al. (2012a) and Christensen et. al. (2012b).

Using the outcome of the initial shape and size optimisation the topology optimisation results were used to guide structural hard point locations and attachment points. This ensured the BIW structure created would be "compatible" with the "safety cage", and the primary load paths were maintained throughout the length of the vehicle. This led to the generation of the front crash structure illustrated in Figure 7.

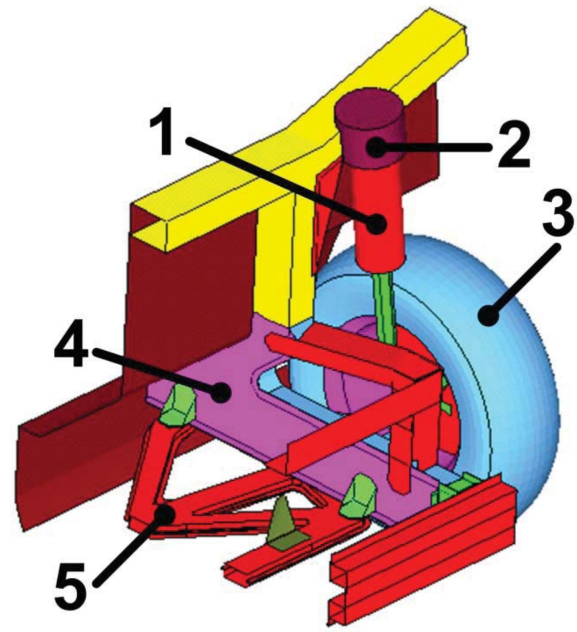

Figure 7 : Initial crash structure

The underlying ideologies behind the design in Figure 7 are highlighted by the following points:

1. **Suspension and wheels.** In order to include the wheels in the crash model, it was necessary to also model the suspension. As this was not specified a MacPherson strut setup was utilised using hard points identified from the topology optimisation, Christensen et. al. (2011).
2. **The shock absorber turret** was placed as far back as possible in order to maximise the crush distance. This was conducted with consideration of the vehicle dynamics.
3. Based on the benchmark and associated analyses the **wheel to sill interaction combined with the subframe deformation** were found to be key parameters of the smart car energy management. Consequently, these were incorporated into the crash structure, as they were likely to have a significant effect on the global crash pulse.
4. The length of the **longitudinals** were maximised in order to increase the available crush distance.
5. **Manufacturability** was considered throughout the development of the crash structure. Therefore, the structure was designed using pressed steel parts. The subframe was intended to be bolted on the BIW from underneath the vehicle, eliminating the need

for the fixings to pass through the main longitudinal sections.

As structural efficiency was a key part of the design spot welds were used to create a stiff but lightweight structure. This meant that the structure was not designed to promote failure for energy management as a function of the assembly. Instead this was to be attained through geometry and a better use of material.

Based on the design illustrated by Figure 7 an FE model was created, as illustrated by Figure 8.

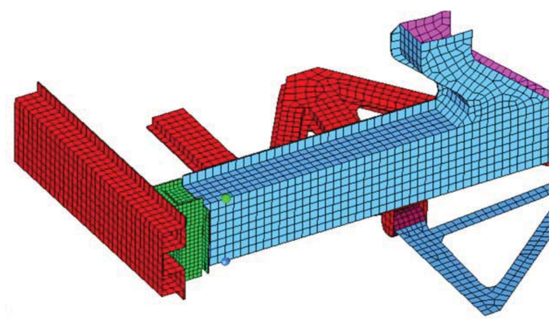

Figure 8 : FE model of front end crash structure

The FE model was subsequently used to run a series of crash model analyses in order to correlate the model in addition to incorporating a series of adjustments in order to meet the criteria identified in section II of this paper.

On completion of the adjustments the performance of the Last Concept Iteration Model (LCIM) the global acceleration pulse was overlaid with the Smart Four Two and the Ford Fiesta pulses. This was done in order to compare the LCIM performance to vehicles with a similar structural configuration, including the class leader for occupant injury reduction. The pulses of the three vehicles in question is illustrated in Figure 9.

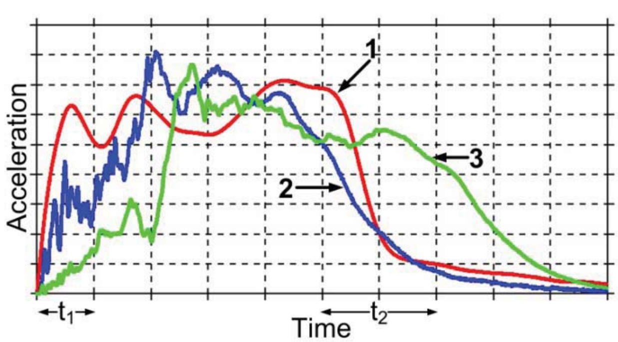

Figure 9 : overlay of crash pulses

The crash pulses of Figure 9 are:

1. LCIM (global pulse).
2. Smart acc. pulse.
3. Ford Fiesta pulse.

Figure 9 demonstrates that the duration of the LCIM pulse is comparable to the Smart pulse, however the average accelerations are higher due to the increased mass of the concept vehicle that LCIM is based on. The peak accelerations of the LCIM is lower than that of both the Smart and the Ford. However, in this connection it should be mentioned that a standard SAE J211 CFC 180 filter, SAE (2012), was applied to the LCIM results in order to remove numerical noise from the curve.

The overalls shape of the LCIM pulse is similar to the Smart most likely as a result of the similar front-end configuration. The short front end of the two vehicles forces early engagement of the tyre to sill contact, which ramps up the accelerations from approximately 30ms, consequently a rear loaded pulse shape occurs.

It must be emphasised that the pulses in Figure 9 are based on simplified modelling of the concept structure in Computer Aided Engineering (CAE), relative to real world vehicles. This does for example result in an overly stiff front end structure (in CAE). This is because a significant amount of crush distance is used for pedestrian protection and low speed insurance rating impact tests in real world vehicles. Consequently the initial crush of the crash structure will have a considerably lower stiffness than the straight steel beam used for the LCIM concept model. This additional crush distance (low stiffness foam compression etc before structure beings to collapse) is likely to be the reason why the duration t_1, Figure 9, is longer on the Smart and Ford vehicles when compared to the LCIM.

The duration of t_2 Figure 9, for the Ford Fiesta impact test is significantly longer than that of the LCIM. This reduces the average accelerations of the occupant(s), reducing the load transferred through the restraint system whilst improving the crashworthiness of the car. Given the short front end forced by the packaging of the LCIM concept vehicle, Christensen et. al. (2011), it is unlikely that a significantly better crash performance than that of the Smart FourTwo can be obtained.

IV. Conclusion

This investigation has focused on the design of vehicle front-end structures for crashworthiness. This has been accomplished by initially benchmarking the crash performance of similar sized vehicles with excellent crashworthiness. This was done in order to fully understand the underlying mechanics of such structures. The investigation then focused on the first stage of the crash event, the structural behaviour of the vehicle itself, as an enabler for the reduction of occupant injuries during crash scenarios.

Five cars were benchmarked and compared, all of which were subject to the NCAP 35mph rigid barrier frontal crash. This demonstrated the fact that the pulse shape is highly dependant upon vehicle configuration. Vehicles with front mounted engines and front wheel drive were found to provide the best characteristic pulse shape for occupant injury reduction (front biased pulse). Data from NHTSA crash tests and modelling were investigated in order to quantify different pulse shapes including the interactions that caused them.

Structural targets were subsequently derived from analysing the NHTSA data. This was used to guide the concept design and development of the front structure of the LCIM. The peak allowable acceleration target was limited to 42g, as this was the peak of the benchmarked vehicles. The dynamic intrusion target for the vehicle was set to the interval of 454-482 mm. The target pulse shape to reduce occupant injury and improve restraint system loadings was defined in Figure 5.

Additional analysis of similar vehicle body structures including crush mode characteristics and materials was then completed before an initial crash structure (loadpath) was defined, taking the outcomes of the topology optimisation into account. This ensured that no discontinuation of loadpaths would occur throughout the length of the vehicle.

Next, shape and size optimisation was used to obtain initial information about the required cross-sectional properties.

Initial model correlation and energy checks where carried out prior to refining the structure, thereby ensuring that the real world physics were represented in the FE model. The stiffness of the initial concept was found to be much too low. Therefore additional studies were conducted in order to develop the global structure stiffness and subsequently a suitable longitudinal crush mode for robustness.

The low speed performance of the structure was also investigated and the crush cans developed to meet the required energy absorbance. Further studies were conducted assessing the mesh convergence which proved the chosen mesh size of x 15 mm to be a good compromise between computational efficiency and result accuracy.

A full crash model incorporating the wheels, sub frame and suspension was created in order to capture the wheel to sill interactions. The incorporation of these assemblies allowed the gauge of the longitudinals to be reduced whilst maintaining the stability of the crush mode, thus improving the structural efficiency of the front-end structure, i.e. reducing mass whilst maintaining performance. This work showed the target pulse shape could not be attained using this vehicle configuration, due to the late interaction of the wheel and sill creating a load path, spiking the reaction force. Peak acceleration was found to be well under the 42g target at 36.6g. Comparing the results to those of similar configuration vehicles found that the shape of the LCIM pulse was comparable. The LCIM concept design could be further developed in order to meet all targets set.

V. Next Steps

To further the engineering of the lightweight front end crash structure of this paper several aspects of the structure, concept development tools, modelling structure, boundary conditions and mass reduction should be revised, including:

Additional structural research. Specific larger vehicles (external dimensions and mass) utilise tapered longitudinals, or swages, to obtain required crush characteristics, this was not found to be the case in the smaller vehicles analysed during the benchmarking exercise. Further studies could be conducted to better understand how the new front end structure could be utilised to control the pulse profile of the LCIM concept, which could lead to improved structural efficiency.

Topology optimisation. This step was conducted using linear static topology optimisation which clearly has severe limitations with respect to crashworthiness, as discussed in e.g. Christensen et al. (2012b) and Christensen et al. (2012c). A truly non-linear topology optimisation algorithm catering for large levels of non-linearity would drastically improve the starting point (primary loadpath definition) for the crash structure.

Boundary conditions. All crash model utilised in the development of the LCIM utilised a rigid bulkhead to constrain the model. This is not truly representative of the motion of the vehicle during impact, and could be improved with the use of a sled model. This would allow the pitching of the car during impact to be captured. Modelling the centre of mass as a point mass and utilising a simple rigid sled would not affect the computational time significantly.

Manufacturing methods. As "traditional" manufacturing methods were considered throughout the development of the LCIM only steel pressings were utilised. Further investigations on the feasibility of other steel manufacturing methods could be analysed in order to further improve the structural efficiency. This could for example include the use of seamless hydro formed parts for structural members, or even other materials. These improvements would also need to include the pressing manufacturing process, which would remap material strains and thinning due to the manufacturing in order to provide a more production-ready solution.

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Power Integrity Requirement of New Generation of ROV for Deep Sea Operation

By O. Sulaiman & A.H. Saharuddin
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Abstract - Remotely operated vehicles (ROVs) system requires powerful vehicles to support the bollard thrust and tool power required for deepwater tasks. Evolving deeper waters, vehicle support for heavy-duty tasks demand, deepwater subsea construction, repair and maintenance require efficient ROV power pack to support these tasks. Typical work-class ROV systems provide maximum power levels ranging from 100 to 200 horsepower that produce impressive thrust in either vertical or horizontal directions. Problem associated with ROV power pack include inefficiencies in the power system designs that limit peak system performance thrust curves, inability of the hydraulic system to adjust to varying demands, environmental concern related to energy usage and ship husbandry. This paper address the design and development of a variable pressure power delivery and propulsion system that significantly increases overall system efficiency to maximize use of available power.

Keywords : Power; Electrical; ROV; Integrity; Deep water.

GJRE-B Classification : FOR Code : 090607

POWERINTEGRITYREQUIREMENTOFNEWGENERATIONOFROVFORDEEPSEAOPERATION

Strictly as per the compliance and regulations of :

Power Integrity Requirement of New Generation of ROV for Deep Sea Operation

O. Sulaiman [α] & A.H. Saharuddin [σ]

Abstract - Remotely operated vehicles (ROVs) system requires powerful vehicles to support the bollard thrust and tool power required for deepwater tasks. Evolving deeper waters, vehicle support for heavy-duty tasks demand, deepwater subsea construction, repair and maintenance require efficient ROV power pack to support these tasks. Typical work-class ROV systems provide maximum power levels ranging from 100 to 200 horsepower that produce impressive thrust in either vertical or horizontal directions. Problem associated with ROV power pack include inefficiencies in the power system designs that limit peak system performance thrust curves, inability of the hydraulic system to adjust to varying demands, environmental concern related to energy usage and ship husbandry. This paper address the design and development of a variable pressure power delivery and propulsion system that significantly increases overall system efficiency to maximize use of available power.

Keywords : Power; Electrical; ROV; Integrity; Deep water.

I. Introduction

Environmental issue has been key driver to today technological decision. Deepwater marine operation has increased due to prohibitive nature of offshore activities in proximity to coastline. Deep water construction posed many challenges. This include the situation of water depth increases and subsequencial requirement for surface vessels size increase in order to support the equipment needed to reach the seabed. This makes the use and demand of ROVs imperative. Consequentially, the source of energy that meets these demands is increasingly becoming important. Energy space, size, and economic energy efficiency is tackled through increase ROV functionality with larger onboard power systems that provide more available thrust to support higher variety of tasks. Subsea equipment and hardware improvement has target effective equipment handling and design of a variable-pressure power delivery and propulsion system for completion of ROVs mission.

All components of an ROV system should be rated to the maximum operating depth of the underwater environment anticipated, including safety factors. Pollution released from ROV devices have really been addressed, and the reality of environmental interaction makes it important for ROV system design to address ship husbandry problem. This paper discusses the potential of using alternative energy hybrid to power ROV system with hope to reduce challenge of air prolusion released to the atmosphere.ROV deep water operation find application in the following areas: FPSO, diving support, research vessel, drillship (Klages m. et al, 2002).

II. System Failure and Risk Based Design Requirement for ROV

In order to improve reliability of system, a generalized version and analytical expression for this important principle have also been formulated for multiple failure modes. It is argued that the traditional approach based on a risk matrix is suitable only for single failure modes/scenarios. In the case of multiple failure modes (scenarios), the individual risks should be aggregated and compared with the maximum tolerable risk. Risk-based design is important in order to minimize the probability of system failure below a maximal acceptable level at a minimum total cost (the sum of the cost for building the system and the risk of failure).

Today, design shift towards knowledge intensive product, risk based design is believed to be key elements for enhancement of industrial competitiveness. The use of risk based design, operation and regulation open door to innovation and radical novel and inventive, and cost effective design solution. Risk based approach for ROV follow well established quantitative risk analysis used in offshore industries. The key to successful use of risk based design require advance tool to determine the risks involved and to quantify the effects of risk preventing/reducing measures as well as to develop (evaluation criteria to judge their cost effectiveness.

ROV operating capabilities requirement that can be investigated is under risk based design are:

- Standardized intervention ports for all subsea with any available ROV.
- Visible mechanical indicator or redundant telemetry channel
- ROV testing requirements
- Electrical power requirement

General requirements - refer to SOLAS requirements, Part D, Chapter II-1 - outlines

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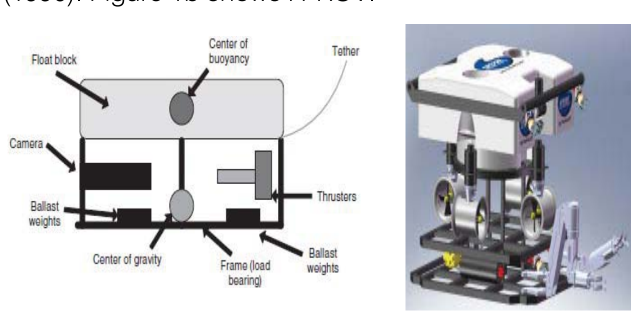
requirements for Ship construction sub-division and stability, machinery and electrical installations

III. ROV System and Subsystem

The ROV system is one of the simplest robotic designs, where complex assignments can be accomplished with a variety of closed-loop aids to navigation. ROV system has its immovable locomotive part and counterparts that are capable to move under its own power. The power of locomotion has ability to navigate the robot, with levels of autonomy to achieve defined mission. Remote operated vehicle (ROV) are built with secondary control of the subsea blowout preventor (BOP) stack, and most provide other tertiary control systems as well.

The ROV intervention capability is limited on some subsea BOP stacks while others have the ability to control multiple functions. ROV intervention capabilities for secondary control of all subsea BOP stacks, including the ability to close all shear and pipe rams, close the choke and kill valves. Deep water operation requires larger component wall thicknesses are required for the air-filled spaces (pressure-resistant housings) on the vehicle. This increased wall thickness results in an increased vehicle weight, which requires a larger floatation system to counter the additional weight. This causes an increase in drag due to a larger cross-section, which requires more power, hence large cable to become larger.

Today design culture is embracing the open source computer-based control models that allow users to design their own navigation and control matrix. This concept allows development of new techniques; define by the user's imagination. Open source platform take the control of the development of navigation capabilities including the mission from the hands of the design engineer (who may or may not understand the user's needs) into the hands of the end user (who does understand the needs). Cost efficient design of the systems with the user in mind is critical to the success of the ROV and the mission. Saving weight is also key cost-effective design and operation. Figure 1a sows components of ROV that must be incorporated in the design spiral of the electrical requirement (Michel J.-L. (1990). Figure 1b shows H-ROV.



a. b.

Figure 1 : ROV parts

The vehicle power system can be conveniently divided into transmission and distribution systems, which are described in sequence below. The transmission and distribution system protoyped mode is encouraged to designed, built, and tested before scale up and deployment. ROV subsystem includes (Renard V. et al (1993) :

- lighting,
- cameras,
- sensors and
- manipulators
- electrical

Recent year have seen development of third generation ROV with Hybrid ROV that utilize hybrid design, one of such design is H-ROV which was developed in collaboration with Data Response Kongsberg by Sperre AS. H-ROV is built with an advanced propulsion system, auto-tracking, and an ingenious multiple control tool platforms for subsea DP and auto-traction operations. The redundancy system can benefit from robust electrical system design.

IV. UMT Rov – Stealth 2

The Stealth Remotely Operated Vehicle by Shark Marine Technologies Inc., is versatile ROVs on the market today. Small in size and portable with many features and capabilities. The Stealth ROV is packaged with plug and play ready for such options as scanning sonar, manipulator arm, sub-bottom profiler, and total positioning system.

The size and weight (45kg) of this ROV system allows for operation from even small boats or inflatables. The Stealth2 computer controller with its daylight viewable, graphical interface, allows completely automated control of the ROV functions. Settings are provided for auto-depth, auto-heading, auto altitude and vertical trim as well as for monitoring the ROVs internal environment. The computer controller may also be used for processing other Windows based options such as sonar or vehicle tracking. On-screen displays simplify navigation and provide valuable information during video playback as well as efficient high quality recordings of video, jpg and .mpeg. Figure 2 shows UMT Stealth ROV.

Figure 2 : UMT Stealth ROV

The stealth can also fulfill other mission with manipulator arms, cutting arms, scaling lasers, various cameras; including zoom features or extreme low light, tracking systems, sonars; including multiple receiver units and sub-bottom profilers, gradiometers, magnetometers, recovery tools, cable reel systems and more. The stealth has application in different underwater operations from inspection services, to search and recovery, to environmental studies, to archaeological investigations. Vehicles are presently in use the world round by various navies, marine institutes, logging companies, underwater recovery units, commercial dive operations and more. Table 1 and 2 shows specification of the stealth.

Table 1 : Specifications

Vehicle Dimensions:	30"L X 22"W X 18.5 inc. handle
Vehicle Weight:	90 lbs. (40 Kg)
Controller Dimensions:	21"W X 18"D X 9"H
Controller Weight:	44 lb. (20Kg) (Including Hand Control)
Hand Control Dimensions:	7.5W x 7.5"D x 3"H
Hand Control Weight:	4 lbs. (1.8 kg)
Hand Control Cable length:	15 ft. Standard (longer optional)
Neutral Umbilical Description:	Urethane Jacket with TPR floatation jacket, 1000 lbs. minimum Breaking load
Neutral Umbilical Size:	0.53" diameter (12.7 mm)
Neutral Umbilical Length:	500 ft. Standard (up to 2000 ft. optional)
Neutral Umbilical Weight:	52 lbs. per 500 ft. (20 kg per 150 m), Dry Weight
Horizontal Thrusters:	2 each, 1/3 Horsepower
Vertical Thrusters:	2 each, 1/3 Horsepower
Lighting:	2 each 150 watt quartz - Variable control
Camera:	High resolution Colour 450 TV line (others optional)
Camera Motion:	180 degrees viewable (pan optional)
On Screen Display:	Depth, Heading, Date, Time, Title (Others optional)
Scanning Sonar:	Pre-wired for Plug & Play (Sonar optional)
Depth Rating:	1000 feet (300 m)

V. New Generation Of Rov For Deep Water Operation Challenge Electrical Power Requirement

ROV power performance and efficiency depends on capability to effectively lifting heavy objects, pushing large equipment items into position, and acting as a supply for high-powered tooling at minimum cost, space and time. Increased input power of ROV system means increased electrical current capacity requirements for the umbilical/tether system and increased motor, pump, and thruster sizes. As well as subsequential system changes to support these primary size/capacity increases, use of more copper in the umbilical that requires more steel armor on the cable because weight of the conductors is entirely parasitic. The main components of the power system include (Fouquet Y., 2002)(See Figure):

- Power source,
- the tether,
- data, and
- the connectors.

The ROV is simply a delivery platform for transporting the sensor package to the work location. The Human-Robot Interface (the intuitive interaction protocol between the human operator and the robotic vehicle) is still in its infancy; However, sensors are still outstretching the human's ability to interpret this data fast enough to react to the feedback. Beside this deep sea operation is imposing more requirements for the power design, rating and application of new generation of ROV. The majority of the company's assignments have involved the development of tailor-made solutions to solve specific problems in subsea operations for their customers.

a) Power Distribution System

To satisfy environmental problem, recent design also focus on minimized acoustic emissions, fiber optic telemetry system, and full integration of vehicle, navigation, and science sensor data streams. One of the evolving ROV technologies is the design pioneer by Mbari, where the ROV is designed to operate up to 4000 m depth rating, 100 kg payload with +/-35 kg variable buoyancy adjustment, precision 4 degree-of-freedom vehicle control. Operational features include a quick-change payload toolsled, and extensive onboard fault detection and isolation capability.

The ROV electrical power system to deliver and manage 15 kW of DC electrical power, primarily to meet the vehicle propulsion goals of 1.5 knot free speed and 0.75 knot full depth transit (i.e., with cable drag). The electrical load capability includes 3.7 kW (mechanical output) brushless DC permanent magnet motors. Distribution voltage selection is based on vehicle performance and personnel safety issues. Traditionally ROV vehicle operate mostly at 120V, due to power requirement the industry is adopting 270 and 240 VDC full wave rectification of 120/208 three phase AC for manned submersible, this in line with aircraft power distribution, after apparent that the 5 kW demanded by the largest loads would require large and heavy switches, connectors, and wiring at 120 V. emerging practice for 270 VDC aircraft power distribution, and with. 48 VDC is presently the highest industry standard voltage that can be considered "low voltage" for safety purposes. However, due to deep sea operation environment future ROV will require all electric power operation with high voltage demand. Such system will require the use of SCADA and Distributed Computer System for the vehicle data management system.

The power distribution system include the DC busses, power switches, ground fault detection system, and motor regeneration control system. Mbarry system deisgn employ distribution and control system design where 15 kW of 240 VDC power and 2 kW of 48 VDC power on each of the A and B busses that have synchronization capability and leaves room for future upgrades to the transmission system as well. The ability to detect ground fault conditions on any circuit passing through seawater; the ability to switch off and fully isolate any faulted load circuit; and minimization of personnel exposure to 240 VDC circuits and wiring (See Figure 3a). This diagram shows the values for voltage, current, kVA, and power loss throughout the system, at no load and full load operating points. The system end-to-end load factor or ratio of power delivered to power lost in transmission. This value can be determined after a survey of load analysis requirements, as a tradeoff between voltage regulation and power delivery capability. Figure 3b. typical uninterrupted power system for 480 volt system.

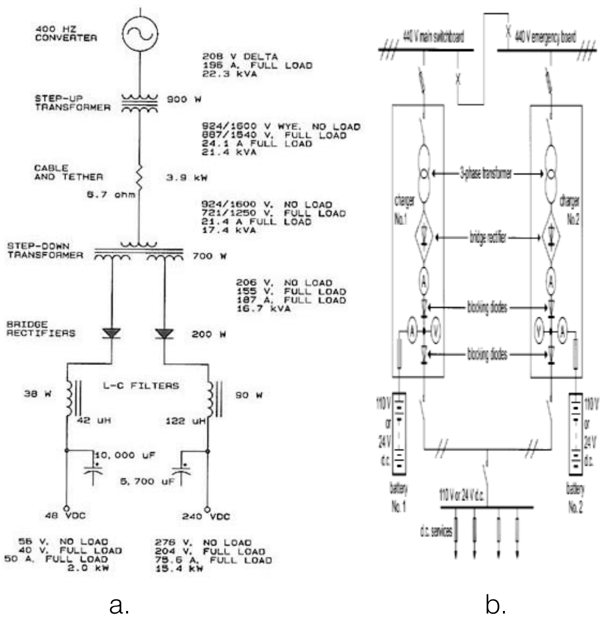


Figure 3 : One – line diagram of power transmission

The standard for work class ROVs is to use electrical power, from the umbilical, which is converted to hydraulic power. This requires an inefficient process that requires a lot of electric power. Electric thrusters could increase the reliability of an individual ROV (See Figure4).

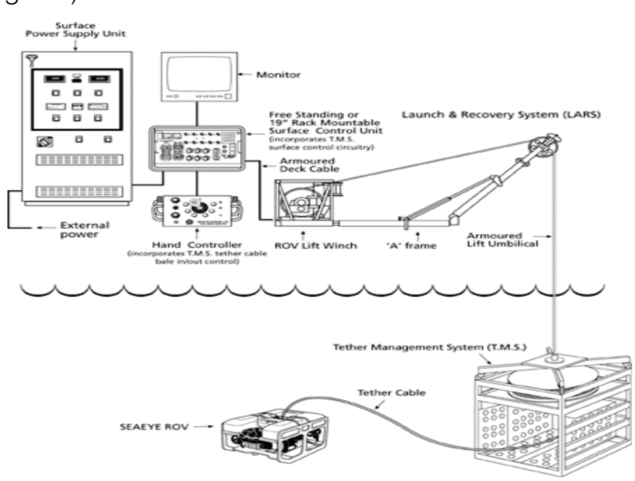


Figure 4 : ROV with umbilical delivery system

The electric ROVs have fewer moving parts so they should be easier and cheaper to maintain over the long term. For ultra-deepwater operation efficient electric could provide more capability than current hydraulic ROVs cannot efficiently access. Traditionally, deepwater ROV designs were beefed-up versions of shallow water designs. What is needed now is change in technology that will generate all-electric ROVs with the power and versatility of the current fleet and the added ability to operate in ultra-deepwater (J. Newman et al, 1992).

An all-electric remotely operated vehicle (ROV) is being popular for deep water operation. They have high reliability, layout flexibility, load diversity and economic part load running, easy control and low noise and vibration. Early ROV designs of every description relied on established electronic technology. In fact, the first ROV, the US Navy's CURV, used to recover a hydrogen bomb off the coast of Spain in the 1950s was all electric. One problems with the all-electric design were that as ROVs got larger, so is the thrusters. An electric-thruster ROV is more efficient.

Another primary reason all-electric ROVs will be used in ultra-deepwater has to do with the umbilical. The umbilical connects the ROV cage to the winch and control equipment on the surface. The umbilical provides power to the unit and communications back and forth between the operator and the ROV. The umbilical also hoists and lowers the ROV and its cage. To handle this strain, and protect the power and communication lines inside, the umbilical is armored by a steel coating. This coating is protective, but also very heavy. The larger the diameter of the umbilical, the heavier the armor. At a certain depth, the size umbilical needed to transmit power to a hydraulic work class ROV would require an umbilical that is too heavy to support its own weight. The steel would no longer do the job. That require lightweight alloy such as titanium, or to Kevlar. Titanium would work, but is prohibitively expensive, as is Kevlar. Figure shows a typical system for All electric system.

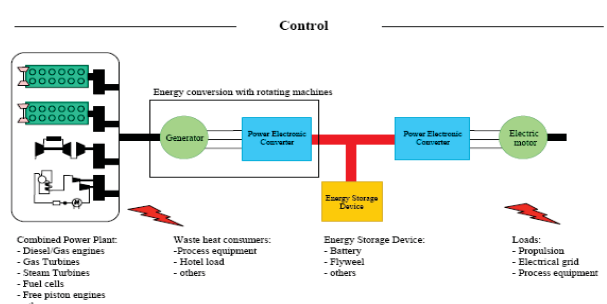


Figure 5 : All electric system

The university of Alaska in collaboration with industry are developing a new ROV system capable of rapid accost effective scientific response to dynamic underwater events such as hydrothermaldiking, catastrophic shelf slumping, phytosplanktonblooms and other transient phenomena. The general schematic includes (See Figure 5):

- surface control console with pilot monitors and control,
- remote science and monitoring stations, and deck cabl,
- winch, CTD cable and depressor weight,
- vehicle tether and vehicle and
- scientific payload

Safety for 240 V circuits are restricted to high power loads that are not frequently opened, and the circuits appear in only a limited number of wiring junction boxes. Both the 240 V and the 48 V systems is required to be fully isolated from frame ground, and ground fault monitor circuits to warn if the impedance to ground falls low enough to cause a hazardous condition. It is therefore essential that personnel are trained in safe working practices for these voltages. This will mean a considerable increase in the electrical content of all training.

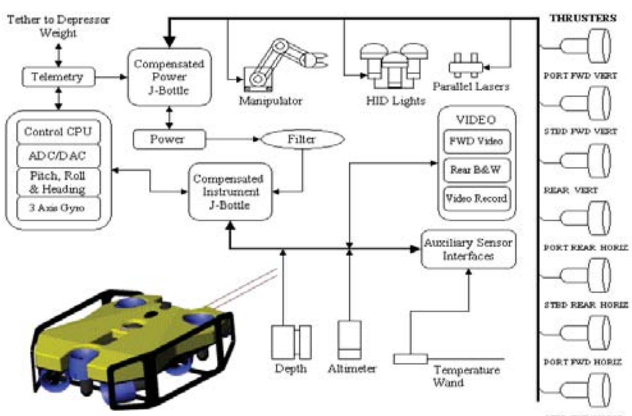


Figure 5 : ROV Distribution system

b) Power Source requirement

Electrical power transmission is an important factor in ROV system design due to their effect upon component weights, electrical noise propagation and safety considerations. The ROV power system design involves series of compromises and trade-off of cost, safety, and needed performance. The power system design reflects the overall vehicle. The design involve an iterative process that starts with goals for vehicle payload, operating depth, speed, support ship size, and vehicle and cable technologies. The payload, depth, and speed are derived from science requirements. , the size is defined, and most technology choices are chosen based on common science and acceptable flexibility for required schedule and resource constraints. Payload and depth requirements and propulsion system are deduced from vehicle size and frontal area.

Consideration for choice between AC and DC is another challenge in the power design. Direct current (DC) allows for lower cost and weight of tether components; Since inductance noise is minimal, it allows for less shielding of conductors in close proximity to the power line as well as weight considerations for portability, and the expense of power transmission devices. Alternating current (AC) allows longer transmission distances than that available to DC while using smaller conductors as smaller systems use only DC as their power source. Submersible systems attempting to escape a hazardous bottom condition have been known to lose power at critical moments while the vessel is making power-draining repositioning thrusts on its engines. This can cause entanglement of the vehicle. submersible maneuvering power can be separately provided.

With the advent of the lightweight micro-generators for use with small ROVs, the portability of the ROV system is significantly enhanced. Battery/inverter combination for systems AC and DC power also contribute to light weight effort. Emergency system power source capable of uninterrupted power to the system at its maximum sustained current draw for the length of the anticipated operation is also a necessity for design requirement. On larger ROV systems, AC power is used for the umbilical due to its long power transmission distances, which are not seen by the smaller systems. AC power in close proximity to video conductors could cause electrical noise to propagate due to EMF (electromotive force) conditions.

Larger work-class systems require the use AC power transmission from the surface down the umbilical to the cage (the umbilical normally uses fiber-optic transmission, lowering the EMF noise through the video) since the umbilical does not require neutral buoyancy. At the cage, the AC power is then rectified to DC to run the submersible through the neutrally buoyant tether that runs between the cage and vehicle. Uninterrupted power supply system is important to sustain power requirement of ROV and its recovery system. Potential energy source for ROV are:

- Fuel Engines combustion engine could operate in form of:
- – Internal combustion engines – Diesel engine
- – External combustion engine – Braytoncycle (gas turbine) engines, Steam engine
- Batteries and Fuel Cells – Electrochemical processes at work

  – Canonical battery technologies
  – Fuel cell characteristics
- Others : Nuclear power sources, renewable energy,
- emissions, green manufacturing, primary batteries, generators

Size and weight of power system matter in the design and estomattion of resistance of marine vehicles, Figure 6 gives size standing information of power source uption.

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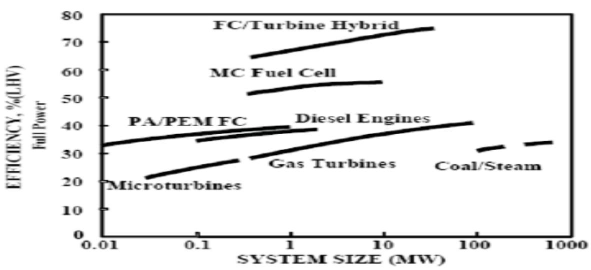


Requirement of power systems for marine applications include:

- Shows typical continuous UPS DC supported supply system
- Essential DC services supplied from 440V through charger 1 - continuously in trickle charges
- During power loss, battery should be able to maintains transitional supply while emergency generator restores power to emergency board & charger 2
- Either battery is available for few hours if both generators are unavailable
- Some critical emergency lights should have internal battery supported UPS i.e. battery charge continuously during non emergency conditions
- Main Supply of power energy source must be carried on board; has to last days, months, years.
- Weight and volume constraints may be significantly reduced compared to terrestrial and esp. aeronautical applications.
- Reliability and safety critical due to ocean environment.
- Capital cost, operating costs, life cycle analysis, emissions are significant in design, due to large scale.

Understanding of the science of energy is also important requirement. Energy can be produced through electrochemical, combustion, electromagnetic, heat, mechanical system alternative or their combination. Electrochemical process involve engines convert chemical energy into heat energy or mechanical or kinetic energy where 1 MegaJoule is: 1 kN force applied over 1 km;1 Kelvin heating for 1000 kg air;1 Kelvin heating for 240 kg water; and 10 Amperes flowing for 1000 seconds at 100 Volts. Table show various heating content for available energy option for ROV.

Table 3 : Energy source fuel heat content

• Fuel	• Heat content(MJ/KG)
• Gasoline(C8H15)	• 45
• Diesel(C13H23)	• 42
• Propane(C3H8)	• 48
• Hydrogen(H2)	• 130
• Ethanol(C2H5OH)	• 28

C8H15+47O2->32CO2+other product

Gas turbines are preferable due to extremely high power density, and the high thermal energy content of traditional fuels. Li-based batteries now available at ~0.65MJ/kg (180kWh/kg); gold standard in consumer electronics and in autonomous marine vehicles. Fuel cells are still power- sparse and costly for most mobile applications, but continue to be developed. They are more suitable for power generation plants in remote locations. Example of specification of gas turbine engine that can be used for ROV is

LM2500 Specifications –

" Output: 33,600 shaft horsepower (shp)

Specific Fuel Consumption: 0.373 lbs/shp-hr

Thermal Efficiency: 37%

Heat Rate: 6,860 Btu/shp-hr

Exhaust Gas Flow: 155 lbs/sec

Exhaust Gas Temperature: 1,051°F

Weight: 10,300 lbs

Length: 6,52 meters (m)

Height: 2.04 m

Average performance, 60 hertz, 59°F, sea level, 60% relative humidity, no inlet/exhaust losses, liquid fuel, LHV=18,400 Btu/lb "

http://www.geae.com/aboutgeae/presscenter/marine/marine_200351.ht

Energy storage technology remains a challenge for the use of alternative energy for ROV. An example of a simple battery would be one in which zinc and carbon are used as the electrodes, while a dilute acid, such as sulfuric acid (dilute), acts as the electrolyte. The acid dissolves the zinc and causes zinc ions to leave the electrode. Each zinc ion which enters the electrolyte leaves two electrons on the zinc plate. The carbon electrode also dissolves but at a slower rate. The result is a difference in potential between the two electrodes.

The Dry cell is relatively inexpensive and quite portable. The anode consists of a Zinc is placed in contact with a moist paste of $ZnCl_2$ and NH_4Cl. A carbon rod surrounded by MnO_2 and filler is the cathode. The cell reaction vary with the rate of discharge. Lead acid cell are electrodes of lead and lead dioxide, dipping into concentrated sulfuric acid Nominal discharge rate C is capacity of battery in Ah, divided by one hour (typical). Lithium primary cells can reach 2.90 MJ/l. Table 4 and Figure 8 show performance battery.

$P_b -> Pb^{2+} + 2^{e-}$ (Oxidixed) or

$P_b + So4^{e-} + 2^{e-} -> P_bSo4 + 2^{e-}$

Gatherin electron at the positive electrode

$Pb^{4+} + 2^{e-} -> Pb^{2+}$ (reduced) or

$Pb^{2+} + So_4^{2-} + 4h^{+} - 4h^{+} -> 2Pbso_4 + 2h_2o$

Total chemistry of the lead acid

$Pb^{2+} + So_2^{2-} + 2so_4^{2+} + 4^{+} -> 2Pbso_4 + 2h_2o$

Table 4 : Comparison of Battery Performance

	Energy density(MJ/KgMJ/i	Memory effect	Maximum current	Recharge efficiency	Self – discharge %/min at 293k
Lead -acid	014, 0.36	No	20c	0.8-0.94	??
Ni-Cd	o.24, 0.72	Yes	3c	0.7-0.85	25
NiMH	o.29, 1.08	Yes	0.6c	-	>20
Li-ion	o.43-072, 1.03-1.37	No	2c	-	12

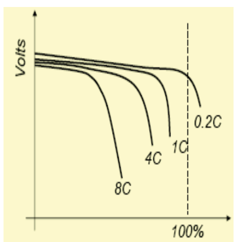


Figure 8 : Battery performance

Typical Fuel cell employ electrochemical conversion work likes like a battery, but the fuel cell is defined as having a continuous supply of fuel.

At anode, electrons are released:

$$2h_2 -> 4h^+ + 2^{e-}$$

At cathode, electrons are absorbed:

$$0_2 -> 4e^- + 4h_2o$$

Fuel cell have high sensitivity to impurities: e.g., PEM FC is permanently poisoned by 1ppb sulfide. Weight cost of storage of H2 in metal hydrides is 66:1; as compressed gas: 16:1 while oxidant storage: as low as 0.25:1. Reformation of H2 from other fuels is complex and weight inefficient: e.g., Genesis 20L Reformer supplies H2 at ~ 0.05 kW/kg. Fuel cell also have characteristics to change load rapidly.

c) *Power Transmission Conversion and Transformation Requirement*

The power transmission system include the shipboard power source, step-up/step-down transformers, vehicle cable and tether, and power conversion equipment required to produce DC distribution power aboard the ROV. Once vehicle size, depth, and speed are determined, the main cable, power transmission system, and propulsion system co-designed can be taken through iterative process. AC and DC power distribution choice and routing is very important in the design of ROV.

Power conversion for the system involves the use of solid state rectifier (diode, SCR). These converters are also example of game changer in the decision analysis for use of AC/DC and hydraulic system. But they also require protection of large semiconductors, e.g. thyristors, which can additionally be destroyed by a fast rate-of-change of. Voltage and current caused by rapid switching. To suppress a rapid overvoltage rise (dv/dt) across a thyristor an R-C snubber circuit is used. Its action is based on the fact that voltage cannot change instantaneously across a capacitor. The series resistor limits the corresponding current surge through the capacitor while it is limiting the voltage across the thyristor. Significant heat will be produced by the resistor which, in some applications, is directly cooled by water jacket. An in-line inductive effect will limit the rate-of-change of current (di/dt) through the thyristor. (E. Mellinger, 1986). Special fast-acting Line fuses may be used as back-up over current protection for the thyristors. Circuit protection for the electric propulsion units (including excitation and harmonic filters) principally employs co-ordinate protective relays. The parallel of a conventional AC relay with solid state devices, in this case Insulated Gate Bipolar Transistors (IGBTs) provide arcless make and break for the DC current, while the relay contacts carry the steady state load with only a few watts loss. Logic on the card sequences, the switching events and responds to overloads, and a shunt resistor and A/D converter allow current to be sensed and reported (See Figure 9 a and B show SCR system and protection (J. Schaeffer,1965).

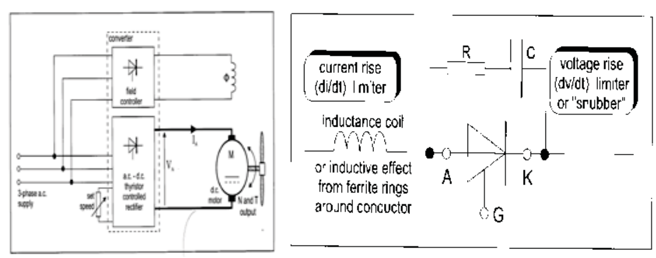
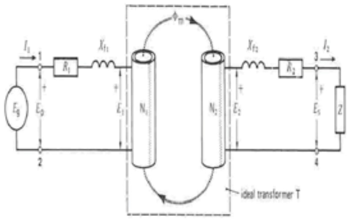


Figure 9 : a. SCR operation b. SCR protection

Power transformation include the use of step-up and step-down transformers with use of material that target less losses - no load (iron) and full load (copper) losses. The transformation also depends on the connection (delta, wye, delta) arrangement of input, cable, and output circuits that can minimize the current waveform crest factor presented to the converter, so that each transformer has a delta winding for harmonic current control and a wye high voltage winding for minimum insulation stress. The vehicle step-down transformer contributes significantly to vehicle mass and volume budgets, and of scientific importance, to the vehicle acoustic signature as well. Figure 10 a and b show power transformer and converter system.



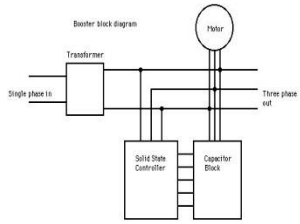
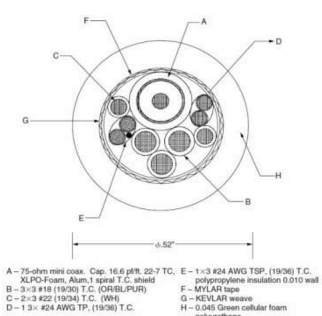


Figure 10 : a. Power transformer b. Power converter

Transformer noise is largely due to core magnetostriction, and thus is present, and in fact maximum, when motors are off, loads are small, and input voltage is high, as during "quiet sub" operation. Reductions of transformer mass and volume are desirable, but these increase core flux level and winding current density, and thus increase both noise and thermal output. The keys to a small, light, quiet transformer thus became getting the waste heat out while keeping the noise in. This in turn meant breaking the acoustic path to seawater with an absorptive layer or a sharp discontinuity in acoustic impedance, while preserving high thermal conductivity. By acoustically isolate the transformer using a gaseous vapor barrier, while using the vapor's latent heat of evaporation to carry the transformer's heat away. The choice of liquid is obviously critical since it must have high dielectric strength in both phases, high latent heat, and material compatibility, not to mention low toxicity, environmental correctness, and low cost. Figure 11 show the tether cross section and the cable sizing requirement (A. Kelley, 1992).

- $$\frac{E_1}{E_2} = \frac{N_2}{N_1}$$



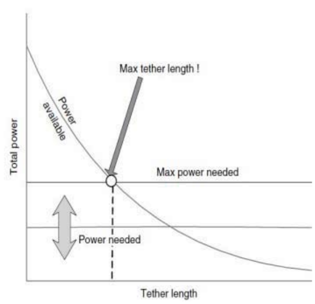
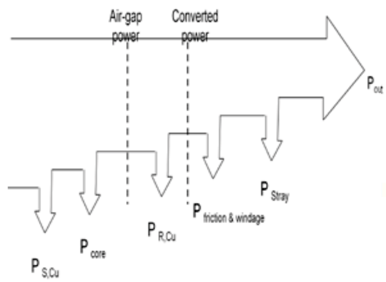


Figure 11 : a. Tether 11 b. Cable sizing

d) Motor and Thruster Control System

The main are connected the propeller for horizontal an vertical thrust. Today, robust motor system comes which thyristor power management system that have control capability for maneuvering propulsion, trusting. On older analog systems, a simple rheostat controls the variable power to the electric motors, while newer digital controls and SCR are necessary for more advanced ROV movements. Figure 12 a and b show motor power requirement and torque speed characteristics.



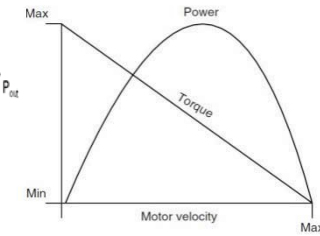


Figure 12 : a. Motor Power characteristics 12 b. Torque speed

$$S_{input} = \sqrt{3}.V_{line}.I_{Line}.....VA$$

$$\eta = \frac{p_{shaft}}{p_{input}} = \frac{p_o}{p_{in}}$$

$$P_f = \frac{p_{input}}{S_{input}}$$

Regeneration control reflect behavior of motors like generators during braking, this lead too high frequency voltage. High bandwidth thrust control, necessary for precision vehicle control, is expected to require frequent and repetitive motor braking, in order to minimize thruster response time.

e) Power Connector (Cable and Tether)

Umbilical refer to the cable linking the surface to the cage or tether management system (TMS). Tether is the cable from the TMS to the submersible. Any combination of electrical junctions is possible in order to achieve power transmission and/or data relay. AC power may be transmitted from the surface through the umbilical to the cage, where it is then changed to DC to power the submersible's thrusters and electronics. Further, video and data may be transmitted from the surface to the cage via fiber-optics (to lessen the noise due to AC power transmission), then changed to copper for the portion from the cage to the submersible, thus eliminating the AC noise problem. The umbilical/tether also should have strength member allowing for higher tensile strength of cable structure and Protective outer jacket for tear and abrasion resistance. The tether length is critical in determining the power available for use at the vehicle following law of resistance and Ohm law. The power available to the vehicle must be sufficient to operate all of the electrical equipment on the submersible. The maximum tether length for a given power requirement is a function of the size of the conductor, the voltage, and the resistance (G. Wilkins, 19987).

$$R = Ro\, l / A$$

$$V = IR$$

Table 5 : Standard copper wire gauge resistance over nominal lengths (Deep Sea Power and Light)

Wire gauge	Ohm/1000ft (approx)
20	10
18	6
16	4
14	2.5
12	1.5

Salt water is highly conductive, causing any exposed electrical component submerged in salt water to short to ground. The result is the 'Ubiquitous ground fault'. The purpose of an underwater connector is to conduct needed electrical currents through the connector while at the same time squeezing the water path and sealing the connection to lower the risk of electrical leakage to ground. The underwater connector is lined with synthetic rubber that blocks the ingress path of water while allowing a positive electrical connection. Connectors sometimes experience cathodic delamination, causing rubber peeling and flaking from the connector walls. Connector maintenance (Figure 3.16) include (N. Forrester, 1982):

- Use small amounts of silicone grease to lubricate the connector, thus allowing easier slide on and off. Using too much grease, a widespread problem, can interfere with sealing.
- Always pull the connector by its body instead of its tail (cable), since the wire splice is located in the connection. Pulling on the tail could part the solder joint and ruin the electrical continuity within the connector.
- Keep the connectors as clean as possible through regularly scheduled maintenance tasks that include cleaning the contacts and lubricating the rubber lining.
- Spray the connector body with silicone spray to keep the housing from drying out, which could result in flaking and rubber degradation.

The connector materials must be able to withstand the environmental conditions without degradation. The physical size of the connector, its weight, ease of use (and appropriateness for the application), durability, submergence (depth) rating, field reparability, etc. should all be assessed. Other important requirement for cables include insulation spacing and right-of-way, operating capacitance and charging current, transmitted power, reliability and installation costs. Design element of cable includes metallic covering, outer coverings and corrosion protection, losses and temperature factors.

f) Power safety Stabilization Requirement

Power safety and harmonic stabilization are very important part of high demand regime of ROV vehicles. For the typical distribution arrangement earlier mentioned, power stabilization can be provided by four rectifier bridges actually contain Silicon Controlled Rectifiers (SCRs) which are fired by zero-crossing circuits and operate in on/off mode as electronic circuit breakers for their associated power busses. Fast fuses at each rectifier input protect against SCR or other catastrophic failure. Each rectifier bridge is followed by an L-C filter that reduces output ripple voltage, and reduces harmonic currents drawn from the power transmission system. Positive Temperature Coefficient (PTC) thermistors are used as constant-power capacitor bleeders

Two design features that increase the operational availability of the vehicle power transmission system are redundancy and fault tolerance. Redundancy incorporates the use of dual power busses for each distribution voltage. Thrusters are arranged so that failure of one 240 V bus leaves one vertical plus two horizontal thrusters available (lateral or fore-aft), which allows yaw control, translation, and vertical motion. The critical loads such as the main computer draw power from both A and B busses through diode-OR circuits. Fault tolerance is achieved through coordinated overload protection plus the ability to selectively isolate loads using switches in the distribution system. Here fuse and circuit breaker current-time characteristics are selected so that the overcurrent device closest to the faulted load trips first, allowing operation on the non-faulted part of the system to resume with minimal interruption. The circuit breakers also function as controlled switches, and are commanded to disconnect loads when a ground fault is sensed on the associated supply bus, again allowing operations to continue.

Grounding implies an intentional electrical connection to a reference conducting body, with specific array of interconnected electrical conductors. Grounding systems should be serviced as needed to ensure continued compliance with electrical and safety codes, and to maintain overall reliability of the facility electrical system. All vehicle electrical systems are fully isolated from frame (seawater) ground. The insulation resistance must be continuously monitored for reasons of safety, and also to provide early warning of seawater intrusion. Figure 12 a and b show the floating ammeter and the preferred ground connection for marine system. The available grounding system include insulated neutral, earthed Neutral and resistance earth Neutral System. The insulted neutral is favored for marine application because of:

- This system is totally insulated from the ship's hull
- This system maintains continuity of power supply to the equipment even in the event of single phasing fault.
- This ensure power supply to critical equipment

- The power supply to the equipment can disrupt only if two single phase faults occur simultaneously in two lines which is then equivalent to short circuiting faults
- But such fault occur very rare

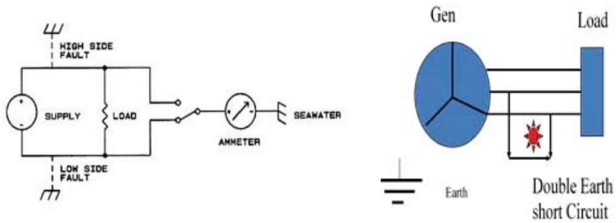


Figure 12 : a. Floating ammeter b. Insulation earthing

Each side of each supply voltage is alternately connected to frame ground through a current limited ammeter. If a ground fault exists on the opposite supply rail, current will flow through the meter. This approach can be extended to monitor several supplies of differing voltages with a shared common rail, at the expense of a more complex troubleshooting flowchart. Action must be initiated to continue to remove, or reduce to a minimum, the causes of recurrent problem areas. Personnel are encouraged to become familiar with Article 250 of the National Electrical Code (NEC), which deals with grounding requirements and practices. Factors which influence the choice of selecting system ground

- voltage level of the power system,
- transient over voltage possibilities,
- types of equipment on the system,
- cost of equipment,
- required continuity of service,
- quality of system operating personnel and
- safety consideration including fire hazards.
- Distribution systems of ships are usually have their neutral points earthed to the ship's hull through a resistor
- The resistor in neutral line limits earth faults currents and protects equipment

g) Power Switching, Telemetry and Control

Power switches were required for each load, or group of loads, on the vehicle for power tolerant. High power DC switching is more difficult, due to two practical issues. Mechanical switching elements require elaborate arc suppression measures (vacuum or arc blowout), since unlike AC current, DC has no naturally occurring zero crossings that allow the arc plasma to dissipate. Solid state switching elements inevitably have a few volts of "on" state voltage drop, and generate dozens of watts of waste heat. Both problems make compact packaging difficult(M. Chaffey, 1993).

It is important for ground fault isolation of the load to have switch control and telemetry as part of the ROV distributed data system. Some could have Instrument Bus Computer (IBC) switches are rated in amapere and voltage, mostly power by MOSFETs, driven directly by photovoltaic optoisolators. Shunt resistors allow current to be sensed by an onboard A/D converter and reported over the backplane..Beside the switch other power interlock devices that can be employed for switch board system are circuit breaker. Circuit breaker comes in forrm of air circuit breaks, oil circuit breakers, air-ballast circuit breakers, gas (sf6-sulphur hexafluoride) circuit breakers and vacuum breaker.

Air circuit breaker are used for low voltage where arc chutes and arc contacts are incorporated. Air blast circuit breakers is a different type that are use for high voltage line , they can handle high pressure at about 30kg/cm^2 air blown during the operation of circuit breaker, thus the operation is too noisy. Oil circuit breaker normaly use Napthenic base petroleum [$(CH_2)n$] wich have been carefully refined to avoid sludge or corrosion. the are expected to excellent dielectric strength high thermal conductivity and prone fire prone to fire hazard, leakage/contamination.SF_6 circuit breaker is most accepted circuit breaker, it is made of chemically very stable, non flammable, non corrosive, non poisonous, colorless and odorless gas with Limits the sonic velocity (1/3 of air). It has Excellent dielectric strength, about twice of air. it can be used for high voltage and it has low GWP (global warming potential is high) and Lifetime 3200 years. Vacum circuit breaker can also handle high voltage. The arc remains in the diffused column mode.

The control system controls the different functions of the ROV, this include the propulsion system, switching of the light(s), video camera(s), relay, digital fiber optics, digital, computer and subsystem control interface. The control system has to manage the input from the operator at the surface and convert it into actions subsea. The data required by the operator on the surface to accurately determine the position in the water is collected by sensors (sonar and acoustic positioning) and transmitted to the operatoror. Control systems are program to maintain required sequence and feedback operation. Today most control system utilizes PLC (Programmable Logic Computer). This is used in numerous manufacturing processes since it consists of easily assembled modular building blocks of switches, analog in/outputs, and digital in/outputs. Control stations vary from large containers, with their spacious enclosed working area for work class systems, to simple PC gaming joysticks. Figure

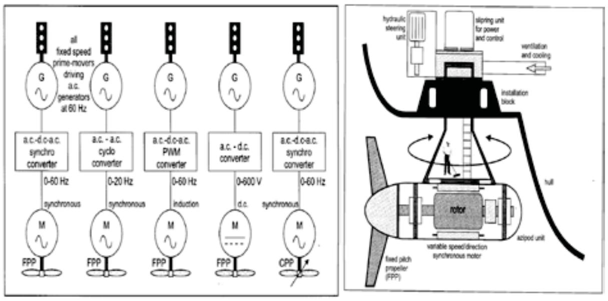


Figure 13 : a. Motor frequency control 13 b. Azipod system

With the rise of robotics as a sub-discipline within electronics, further focus highlighted the need to control robotic systems based upon intuitive interaction through emulation of human sensory inputs. Digital control systems arose, more complex control matrices could be implemented much more easily through allowing the circuit to proportionally control a thruster based upon the simple position of a joystick control coupled with programmable logic circuits interface. The more sensors available to the 'human' that allow intuitive interaction with the 'robot', the easier it is for the operator to figuratively operate the vehicle from the vehicle's point of view.

h) Data Transmission and Protocol

Most ROV have spare twisted pair of conductors for hard-wire communication of sensors from the vehicle to the surface. This make sensor system to not need engineering support from the ROV manufacturer in order to design these sensor interfaces. The weakness is incompatibility of the transmission protocol to share the single data line, only one instrument may use the line at a time. Available industry standard protocols for transmissions is TCP/IP, RS-485, and RS-232, while useful and seemingly ubiquitous in the computer industry, is distance limited through conductors, thus causing transmission problems over longer lengths of tether. The move toward open source PC-based sensor data processing has led to the production of data protocol converters for use in ROV sensor interpretation. Most small ROV sensor manufacturers transmit data with the RS-485 protocol, requiring a converter at the surface to both isolate the signal and to convert it to USB (or RS-232) protocol for easy processing with a standard laptop computer. Standards for these protocol converters are slow in evolving (due to the size of the customer base).

VI. Conclusion

The challenges of proactive culture towards accident occurrence near population and prevention of environmental consequence of accident evolved requirement for maritime activities to operate deep water. The importance of ROV in development of new technology to meet this challenges is highlighted, this include, data collection, installation and monitoring. Likewise, the need for more power is highlighted and system requirement to meet power requirement ROV for deep water Operation is discussed. ROV system integrator must become familiar with the wiring and pin arrangement for these converters that will be instrumental to HVDC to ROV system as well as to assure data transmission from the sensor, through the vehicle and tether to the software at the surface, is achieved. Power sensor and data throughput reliability promise greater the ability for deepwater to deliver to the operator the necessary job-specific data as well as sensory feedback needed to properly propel,. Maneuver and control ROV for deepwater operation.

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Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

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All manuscripts submitted to Global Journals Inc. (US), ought to include:

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Abstract, used in Original Papers and Reviews:

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Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

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The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

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Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

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10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

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21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

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26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

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33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

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Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page

- Separating a table/chart or figure - impound each figure/table to a single page
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In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

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- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
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- Center on shortening results - bound background information to a verdict or two, if completely necessary
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- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

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- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

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- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
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- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

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The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
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Approach

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- Give details all of your remarks as much as possible, focus on mechanisms.
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- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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