TMS Design and analysis of ITB ultra deep ROV

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ITB Ultra deep ROV have the operating depth until 3000 msw (meters salt water). With this very long distance, need some consideration to support the ROV can work effectively. By the very long cable it is very hard to handle directly on free swimming mode. TMS (Tethered Management System) is one of additional system to support on the ROV operation especially for handling the umbilical. This system designed to handling cable tension, power, communication, sea current and effectively operation procedures. This system is depend on the ROV system configuration and also the platform where the ROV will be deploy. This paper will present the general design of ITB Ultra deep ROV TMS and the step by step design aspect to support the ROV operation.

[Keywords: ROV, Tethered management System (TMS), Umbilical]

Introduction
On Recently year, the utilization of underwater vehicle on the marine industry growth rapidly. Even though the highly cost and risk on the development an operate this vehicle, almost there’s no big significant to inhibit the developer or manufacturer to make this kind of vehicle better day by day.

As an Indonesian perspective, the requirement of this vehicle more increase, especially on the Oil and gas industry. Based on international Marine Contractor Association (IMCA) the ROV can divide into 5 class:

- Class I – Observation Class
- Class II – Observation ROVs with Payload Option
- Class III – Workclass Vehicles
- Class IV – Towed and Bottom-Crawling Vehicles
- Class V – Prototype or Development Vehicles.

The ITB ultra Deep ROV will be functioned as workclass ROV. By this requirements and the ultra long umbilical, is highly recommended to equipped with the system that can handling the cable properly. Referred to IMCA code, is highly recommended for ROV with operating depth more than 600 meter must equipped by TMS.

The Ultra Deep ROV specification that had been developing will be describe as follow (Table 1):

Design of ultra deep ROV design and progress results will be illustrated as follow (Fig. 1).

As an additional information, this ROV also used the modular composites dry box that already tested until 300 bar or almost 3000 m operating Depth.

<table>
<thead>
<tr>
<th>Table 1—ITB Ultra Deep ROV Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension (L x W x H)</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Maximum Operating Depth</td>
</tr>
<tr>
<td>Propulsion</td>
</tr>
<tr>
<td>Camera</td>
</tr>
<tr>
<td>Lighting</td>
</tr>
<tr>
<td>Umbilical Capacity</td>
</tr>
<tr>
<td>Control &amp; Navigation Unit</td>
</tr>
<tr>
<td>Additional Payload</td>
</tr>
</tbody>
</table>
Tethered Management System (TMS) becomes a standard solution for operating ROV with very long cable, especially with high current and hazardous environment. It eliminates the effect of drag of the long length of umbilical attached to the ROV. It also provides protection to the ROV during its launch and recovery. Via an umbilical, the ROV transmits survey data to the support vessel.

Some TMS already integrate with Operator console and handling system. The illustration of general ROV TMS in operation will be described as follow (Fig. 2):

Some TMS System that already existing on the word will be described as follow (Fig. 3):

**Materials and Methods**

Step by step methods will be carefully carried out to make efficient and effective development time and cost. There are several main aspect of ROV TMS Design Methods.

- Handling System and Arrangement
- ROV Lock, Latch and Depressor System
- Umbilical selection
- Power and Data Transmission
- Umbilical Spooling Mechanism

Some of those design aspect of this TMS will be more discussed as follow:

**Handling System and Arrangement Design**

There are several handling system and category arrangement type that are already in operation worldwide. Each type have advantage and disadvantage, depend on application. Some of those type will be described on this Fig. 4 below:
Electric TMS, Type 4, Type 5 and Type 6 categorized as Top hat, and another is garage. The TMS system for ITB Ultra Deep ROV designed with Top Hat type, with the several considerations as follow:

- Widely compatibility for several size ROV.
- No need special maneuver system for docking positioning.
- Compatible with ROV that have flat surface on top section like ITB Ultra Deep ROV construction.
- Suitable with ROV that have almost adjacent position between Center of Gravity (COG) and Center of Bouyancy (COB) on X and Y Axis. This figure will be describe the position of the COG and COB on the general underwater vehicle coordinate system (Fig. 5).

General design and arrangement of this TMS will be described as follow (Fig. 6).

Lock/Latch and Depressor Design

Latch and depressor system functioned for locking and retrieval the ROV on the bottom of the TMS System. This system designed to have capacity to hold ROV with the maximum load : 200 Kg. And this system are designed in accordance with DNV Rules for certification of lifting appliances. The latch and termination bullet are delivered as certified pairs to avoid any mismatch between the them. Termination bullet can be designed whole or split to facilitate easy access of umbilical.

Umbilical Selection

All power and data must transmit through this cable. There are 3 type cable that will apply on this TMS.

- Cable from Surface station console to ROV Lift Winch Drum; surface cable, high bandwidth Fiber Optic cable, no armor required.
- Cable from ROV lift Winch Drum to TMS cable drum; underwater cable, High breaking strain capacity, armored, high power, Fiber Optic
- Cable from TMS to ROV; underwater cable, neutral buoyant, minimum bend radius, high bandwidth fiber optic cable.

The variation ROV cable (Fig. 7) already available on the market, some of them can ordered by request (special order) depend on the customer requirement.

Results and Discussion

By series of analysis, finally we can make sure that the system is have an enough safety factor for each critically components.

![Fig. 5—General coordinate system of underwater vehicle](image)

![Fig. 6—The General Assembly of TMS design for ITB Ultra Deep ROV](image)
Lock - Latch and Depressor System Analysis

As explained on the previous discussion, this system must have enough safety factor and reliability to handle the maximum load and also the hazardous environment when this system will operate on the real field. To support the design, the Finite Element Analysis to some critical part will be conducted. One of them is latch and Depressor system. Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

Elements share common points called nodes. Process of dividing the model into small pieces is called meshing. The behavior of each element is well-known under all possible support and load scenarios. Finite element method uses elements with different shapes. Response at any point in an element is interpolated from the response at the element nodes. Each node is fully described by a number of parameters depending on the analysis type and element used.

Static studies calculate displacements, reaction forces, strains, stresses, and factor of safety distribution. Material fails at locations where stresses exceed a certain level. Factor of safety calculations are based on a failure criterion. This FEM Analysis software offers four failure criteria. Static studies can help you avoid failure due to high stresses. A factor of safety less than unity indicates material failure. Large factors of safety in a contiguous region indicate low stresses and that you can probably remove some material from this region. The analysis of this part or component apply the static study and maximum Von Misses criterion as failure criteria.

The Detail analysis of this component will be described as follow:

On the (Fig. 8), the general arrangement and position on the assembling construction will described. This part positioned on the center of construction, to eliminate the unbalance moment during the operation.

After all load and constrain have defined correctly, all of material properties must be defined as well. Some candidate material already iterated in order to find the most effective and efficient material for this application. Material that will be conducted on this analysis will be described on Table 2.

The output of this analysis could served as numerical or graphical. Series of this analysis results will be described on the Fig. 9 (Stress contour analysis results) and Fig. 10 (Factor of safety Analysis).

By this Fig. 10 (color chart) above, the lowest safety factor of this design by this analysis results is 8.

Spooling drum Analysis

Another important system on this TMS is cable spooling system. This mechanism must make sure the cable spooled correctly with enough tension on the drum. Maximum umbilical length that can spooled on this TMS is 200 m. The spooling system that will be conducted on the TMS will apply the bidirectional ball screw. With this ball screw type, the spooling system can spool the umbilical with more accurate and synchronized with the drum rotation. General arrangement of this system will be shown on the Fig. 11.
The tether is spooled onto the drum via series of grooved machined polyurethane liner for the inner wear surface, with this material chosen specifically due to its pliability and unique wear properties, allowing for

<table>
<thead>
<tr>
<th>Model Reference</th>
<th>Properties</th>
<th>Components</th>
</tr>
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<tbody>
<tr>
<td><strong>Name:</strong> AISI 316 Annealed Stainless Steel Bar (SS)</td>
<td><strong>Model type:</strong> Linear Elastic Isotropic</td>
<td><strong>SolidBody 1(Cut-Extrude1)(latch male besar)</strong></td>
</tr>
<tr>
<td><strong>Default failure criterion:</strong> Max von Mises Stress</td>
<td></td>
<td></td>
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<tr>
<td><strong>Yield strength:</strong> 1.37895e+008 N/m²</td>
<td></td>
<td></td>
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<tr>
<td><strong>Tensile strength:</strong> 5.5e+008 N/m²</td>
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<td></td>
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<tr>
<td><strong>Elastic modulus:</strong> 1.93e+011 N/m²</td>
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<td><strong>Poisson's ratio:</strong> 0.3</td>
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<td><strong>Mass density:</strong> 8000 kg/m³</td>
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<tr>
<td><strong>Thermal expansion coefficient:</strong> 1.6e-005 /Kelvin</td>
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<tr>
<td><strong>Curve Data:</strong> N/A</td>
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</tbody>
</table>

| **Name:** AISI 347 Annealed Stainless Steel (SS) | **Model type:** Linear Elastic Isotropic | **<Material_ComponentList1/>** |
| **Default failure criterion:** Max von Mises Stress | | |
| **Yield strength:** 2.75e+008 N/m² | | |
| **Tensile strength:** 6.55e+008 N/m² | | |
| **Elastic modulus:** 1.95e+011 N/m² | | |
| **Poisson's ratio:** 0.27 | | |
| **Mass density:** 8000 kg/m³ | | |
| **Shear modulus:** 7.7e+010 N/m² | | |
| **Thermal expansion coefficient:** 1.7e-005 /Kelvin | | |
| **Curve Data:** N/A | | |

Table 2—Material Properties of Lock-Latch and Depressor

![Stress contour analysis Results](image1)

Fig. 9—Stress contour analysis Results

Fig. 10—Factor of Safety Analysis Results

The tether is spooled onto the drum via series of grooved machined polyurethane liner for the inner wear surface, with this material chosen specifically due to its pliability and unique wear properties, allowing for
additional friction when in contact with the guide cable. Constant tension, smooth, and even spooling will maximize the ROV tether life. The TMS drum and drive sheave are powered using hydraulic motor via chain sprocket transmission to ensure synchronize tether spooling and allowing precise control of tether speed and line tension.

TMS of ITB Ultra Deep ROV will used the Launch and Recovery System (LARS). This system will be attached on the mother ship or support vessel where this ROV will be deployed from.

LARS on the sea operation is very famous. Larger capacity of LARS need the bigger class of mother ship, and it can handle to deploy the higher class of ROV. The design of ITB Ultra Dep ROV TMS will described on the Fig. 12.

Conclusion
From the design and Analysis of TMS for ITB Ultra Deep ROV, we can conclude some information as follow:

- TMS already designed with some analysis to make sure all part will working properly and have enough safety factor 8.
- There are 3 type cable that will used for this TMS system.
- The maximum weight ROV that can attached on this TMS is 200 Kg.

Finally the general specification of this TMS will be described as follow (Table 3).

Acknowledgments
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