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UNDERWATER LASER SCANNER AND ITS POSSIBLE APPLICATIONS

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ABSTRACT

Lasergrammetry is very widely used for terrestrial or aerial operations. However, there is a recent underwater development. Societies of surveying services are increasingly offering this technique to oil companies to carry out certain operations that are currently carried out using inertial or acoustic methods. Metrology represents a crucial point since it intervenes at the very end of the drilling operations. It is therefore very important for oil companies that this step be carried out to produce as soon as possible. The delay of the operations is one of the most important factors that it makes it possible to reduce the time of mobilization of the boat and thus represents a financial gain. Time is not the only important factor for the implementation of a new method since it is also a question of guaranteeing a certain level of precision.

Keywords: metrology, underwater, laser, scanner, triangulation, pulse

1. THE OFFSHORE WORLD

There are different types of petroleum platforms. These can be fixed, mobile or floating. Fixed platforms are used for shallow waters (up to 300 m) while mobile platforms and floating platforms have been developed to extract oil (and/or gas) in deeper waters (up to more than 1500 m). Figure 1 summarizes the different types of oil platforms and their depths of use.

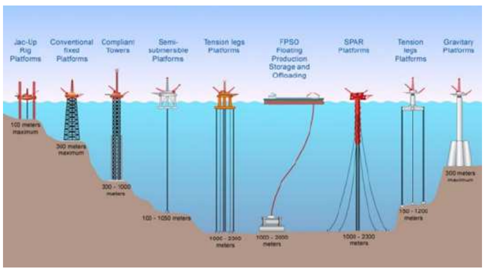

Fig.1. The different types of platforms

A large number of underwater structures are deployed to produce oil. It is necessary to have some knowledge of each of them to understand the purpose of underwater metrology.

A probe is the assembly that manages the flow of oil (or gas) that is pumped from the tank. We talk about production probes when hydrocarbons are extracted from it. There are also water injection probes (or gas) that are not production probes but can improve the production of other probes. Due to the injection probes, water (or gas) replaces the oil already extracted to maintain a certain pressure and thus extract the maximum of a reservoir. Several probes can be connected to a same manifold called manifold. The connection between the probes and the manifold is made using a jumper. The jumper is a pipe that connects two underwater structures to each other, at the hub level. Hubs are connectors that allow the connection between different structures. The link between two

FLETs (Flow Line End Termination) is called spool. Spools are pipes directly connected to a pipeline. They are generally longer than jumpers and have a larger diameter.

Underwater metrology occurs at the level of spools and jumpers. The metrology could be performed on a jumper connecting a FLET and a water injection probe. A FLET is the structure that connects a Flow Line with a jumper. A Flow Line allows fluid transport to improve production. Likewise, PLET (Pipe Line End Termination) are the structures connecting a spool to a pipeline.

The junction between the floating unit and the seabed is provided by flexible pipes, called risers. Risers are used to transport extracted hydrocarbons as well as injection fluids.

In order for probes to work continuously, it is essential to feed them (in electricity and hydraulics) and to be able to control them. This communication is done using a cable called umbilical. Each umbilical is specific to the needs of the field but usually contains a large tube around which there are many small tubes, electrical cables and fibre optic cables. They therefore provide electricity and the necessary fluids to extract hydrocarbons. The link between the umbilical and the installations is via EFL (Electrical Flying Leads) and HFL (Hydraulic Flying Leads) at the SDU (Subsea Distribution Units) as shown in Figure 2.

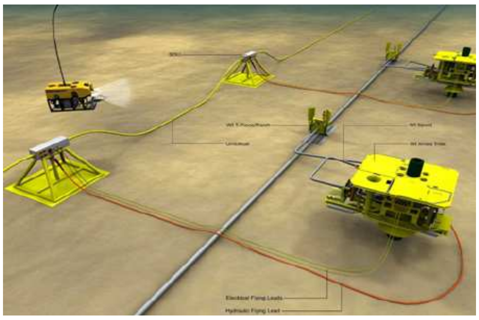

Fig.2. Connections between umbilical and structures

In order to position itself throughout the operations, a network is deployed on the seabed. This network is composed of frames that are fixed supports for receiving acoustic transponders. All these frames are known in coordinates thanks to a combination of GNSS (for the surface) and acoustic (for the underwater environment) positioning. Indeed a specific point of the boat is known by GNSS (Global Navigation Satellite System). This point corresponds to a point of reference for the various submarine positioning systems.

Typically, offshore operations are conducted from installation vessels called Field Support Vessel (FSV). These are specially equipped boats for this type of operation. They allow to proceed with the installation of the various underwater structures. The link between FSV and the underwater world is through the deployment of underwater vehicles. The most used are the Remote Operating Vehicles (ROV). These are remotely controlled vehicles connected to the FSV by an umbilical. This cable ensures the electrical supply of the ROV but also allows their control. It is also through this cable that all information collected by the ROV or by the hardware it deploys is transmitted. Thus, the videos are instantly transmitted to the surface to visualize the operations in real time. Similarly, the data obtained is sent directly to the operator, which allows faster processing, and a live quality control (QC). The time of the submarine missions as well as the effectiveness depend on the experience of the pilot in charge of the operations.

Fig.3. ROV on the SBM Installer Bridge

There are also autonomous systems, AUVs (Autonomous Underwater Vehicles) which are not connected to the surface by an umbilical. They are mainly used for the purpose of mapping the seabed or inspecting the various pipes once installed.

2. UNDERWATER METROLOGY

Underwater metrology is carried out in order to design the pipes connecting the different structures installed on the sea floor. These pipes are jumpers or spools. As can be seen in Figure 4, the connectors at the ends of these lines can be horizontal or vertical.

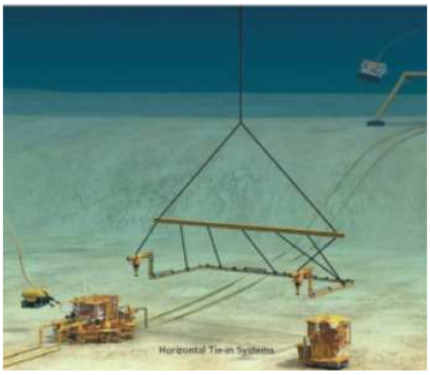

Fig.4a. Horizontal connector

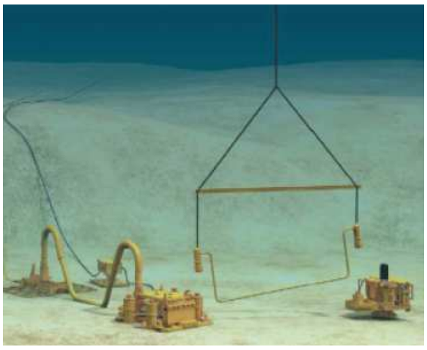

Fig.4b. Vertical connector

Metrology being one of the last steps before the manufacture and installation of the pipe, it is not possible to predict with certainty the date of the operations. The aim of a metrology is to know the relative positioning of one hub relative to the other (relative horizontal and vertical distances between the structures and attitudes of the hubs (pitch, roll, heading), as well as the bathymetric profile along the pipe. Absolute positioning is not necessary.

The measures thus sought are:
- Attitudes of the hubs (roll, pitch)
- Horizontal distance between hub centres
- Depth difference between the two hubs
- Altitude of the hubs in relation to the seabed
- Angular differences between the caps of the connectors and the line between the hubs (angles α and β in Figure 5)

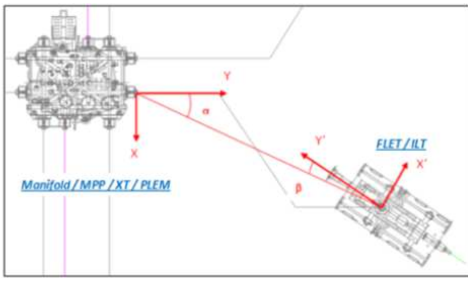

Fig.5. Required actions: Horizontal connector and Vertical connector

Figure 5 shows the angles α and β and the benchmarks for calculating the attitudes of the two hubs (roll, pitch). The Y axis is in the direction of the structure for the horizontal connectors and in the direction of the hub for the vertical connectors. The pitch corresponds to the rotation about the X axis and the roll corresponds to the rotation about the Y axis, as shown in Figure 6:

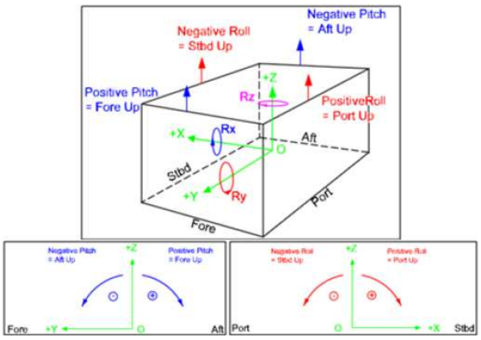

Fig.6. Convention on the attitude of hubs

Precision is an important parameter that guarantees good results. The tolerances depend on the type (spool or jumper, horizontal or vertical), length, diameter and material of the pipe as well as the metrology interface (from the hub or via a receptacle on an observation deck). Care must be taken to differentiate between two types of tolerances, which are the metrology tolerances and the manufacturing tolerances of the pipe. The sum of the two corresponds to the maximum permissible stress so that the operational life of the part is not affected. Thus, a table (listing the distance tolerances of the pipe as well as the angles at the hubs) will have to be provided for each metrology and another table will be provided for tolerances on the manufacture of the part.

Metrology must be conducted from a particular point in the structure. This point is ideally placed in the centre of the hub but it is sometimes impossible to reach from the configuration of the structure. An observation point (OP) is thus created on the structure (this point will generally be materialized thanks to a receptacle ready to accommodate the instrument used for metrology) while taking care to minimize the offset with the hub. as well as making sure that this point is easily accessible for the ROV The distance between the observation point and the hub must be minimal in order to avoid an excessive error spreading during the definition. It should be noted that some techniques do not require the installation of a sensor on the structure, such as photogrammetric method and lasergrammetry.

A dimensional control of each structure is carried out in the context of metrology since it allows knowing the difference between the OP and the hub. It is necessary to differentiate the Dimensional Control (DC), which is a drawing as constructed, and the General Arrangement (GA), which is a drawing of the structure before manufacture. Of course, once built, the structure does not correspond exactly to the GA, only the DC is therefore usable and gives the position of each point of interest with respect to the OP in a system specific to the structure.

Care must be taken to define the coordinate system structure and the attitude conventions used.

The course of a metrology is as follows:
- Planning: the different stages are prepared in advance then the details are discussed again on board the ship;
- Acquisition: data is collected;
- Treatment: the collected data are processed;
- QA / QC: a quality control of the results obtained is carried out in order to guarantee their relevance;
- Report: the deliverable contains all the data necessary to carry out the piping.

Over the years, new technologies have emerged, always with the aim of reducing the time of metrology operations (and thus reducing costs) while respecting precision tolerances.

2.1. EXISTING UNDERWATER METROLOGY TECHNIQUES

Submarine metrology methods have continued to develop. Initially deployed by divers, systems developed today can be installed by ROVs. All operations are thus conducted from the surface. The challenge of developing new systems is to save time while maintaining or increasing the level of accuracy.

2.1.1.Taut wire

Tensile wire metrology is the first used metrology. Divers are mobilized to set up the system and carry out measurements.

They fix a tray containing a protractor on each hub. These protractors are used to measure angles between structures. One of the two deployed units contains the coiled cable that will be deployed to make the distance measurement between the connectors. The other unit receives the cable and contains a crank to allow the wire to be extended. To obtain a certain redundancy in the data, it is possible to block the wire, to wind it up and read the measurements on the surface, or, the precision depending on the visual capacity of the operator, to use the readings of different divers. Additional measures are needed. Indeed, this system requires the use of an inclinometer to obtain attitudes and a pressure sensor (digiquartz) to determine depth differences and bathymetric profile along the pipe. While taut wire metrology is still used in some shallow waters, it has been replaced by many techniques.

Fig.7. Example of a taut wire system

An alternative to this technique (see Figure 8) has been developed to numerically determine the length between the two connectors. More sophisticated, this Digital Taut Wire system is powered by the ROV and attaches to the SWM receptacle of the structure. It contains different sensors, which allows for better distance measurements. An inclinometer is integrated in the system to obtain the attitudes, and a pressure sensor makes it possible to obtain the differences of depth. This technique also provides little redundancy of measurements. Such a method requires little equipment and the system can be quickly deployed, but access to the structure is needed. Deployment by divers is quickly limited as depth increases. In order to adapt the technique to deep water, the systems have been adapted for ROV. Moreover, even if this technique saves time compared to acoustics when there is only one metrology to perform, it is less effective when the number of metrology increases. If this method makes it possible to obtain the angles and distances between the hubs, the bathymetric survey should be carried out separately. In order to obtain a QC of the measurements observed under water, the readings are carried out again on the surface.

Fig.8. Smart-Wire Measuring Unit

2.1.2.Acoustics - PLSM (USBL - Ultra Short Base Line)

PLSM, a French company, has developed a system based on acoustics. This system consists of a measurement base and a pointer that responds to signals sent from the base. The measurement base corresponds to the reference point of the local coordinate system. Units (pointers and bases) communicate with the surface through another unit on the ROV. This allows directing the metrology from the surface, thanks to the software specially designed for these operations, AQUA-CAD. It also allows the drawing in real time to reduce the time of the operation.

In the context of a metrology, a base is fixed on each of the two hubs of future pipe.

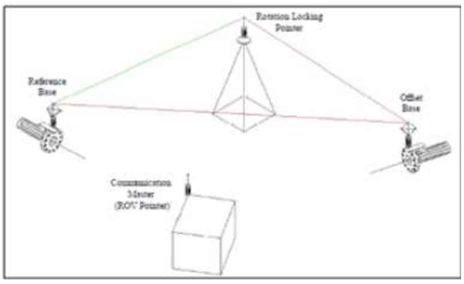

Fig.9. PLSM metrology, direct view line

2.1.3.Acoustics - LBL (Long Baseline)

This method was developed in the 1980s to be a cost-effective alternative to the taut wire method, and it is today the most widely used method. Therefore, if it requires a large number of equipment (initially transported in 10-foot containers), the contractors usually have the equipment on site. The time of such a metrology may vary depending on the experience of the operators (now well aware of the method) and the familiarity of the ROV pilot with such projects.

LBL metrology consists of deploying a network of transponders on the seabed and on the structures in such a way as to be able to measure the distance between the hubs.

A reference network is always set up on the seabed in order to ensure the correct positioning throughout the operations, but during LBL metrology, these permanent frames are not used and temporary frames are deployed in order to obtain the desired level of accuracy by reducing the distances to be measured.

Figure 10 shows the redundancy of the data obtained. It shows that the network makes it possible to determine the distance between the hubs, even though we cannot observe one hub from the other. When there is good visibility between the two hubs (no obstacles), two transponders deployed on the seabed may be sufficient. The goal is always to over determine the distance between the two hubs in order to guarantee a good quality control (QC).

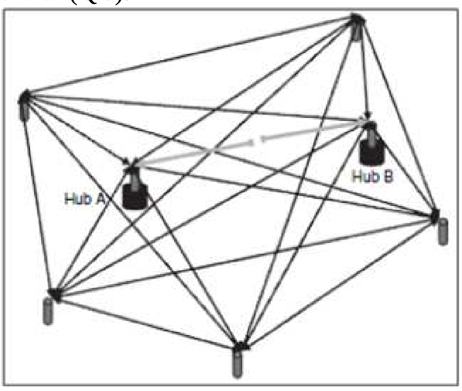

Fig.10. Typical Network for LBL Metrology

Acoustics have many advantages; on the one hand, because they are widely used, therefore well mastered, on the other hand because they can be used even without great visibility and they allow a very good redundancy in the data, which guarantees a good QC. However, the operation is often very long (up to two days when there is no direct line of view between the two hubs), requires the installation of important equipment and mobilizes a greater number of people than the other methods.

2.1.4.Acoustics - 3D Sonar (or Multibeam)

3D sonar's (Multibeam) have recently been developed for underwater metrology. Teledyne Blueview offers a 3D sonar system: the BV5000. Its principle of use is similar to that of the terrestrial laser scanner. The data obtained correspond to scatter plots which can then be processed by the same software as those used for the cloud treatments obtained by means of laser scanners. Instead of using a laser, this system relies on the use of high frequency sound (Teledyne Blueview offers a system using 1.35 MHz sound waves and another using 2.25 MHz waves). They can be deployed on a tripod or from an ROV. Whether tripod or ROV, each option has its advantages and the choice will be made according to the environment and structures.

An advantage of the tripod deployment is the ability to scan at 360 degrees, which is not possible on most ROVs that only scan 180 degrees. The positions of the scans are predefined on the surface from the planes of the structures as constructed. Figure 11 shows an example of the location of different sonar positions during a metrology. Hubs are usually scanned from at least 3 stations. In addition, targets must be installed on the seabed in order to consolidate the different datasets obtained.

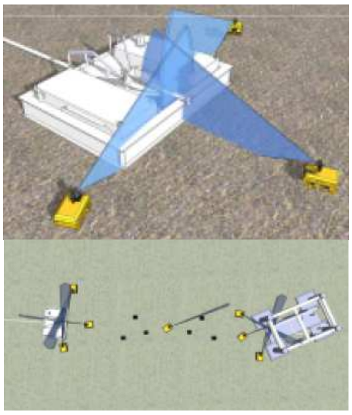

Fig.11. Possible map of the locations of the stations for a complete coverage of the site

2.1.5.INS

Inertial units are increasingly used for underwater metrology. They have the advantage over acoustics of not being impacted by vibrations or underwater noise (which may be due to drilling or other equipment in action underwater). They can also operate in murky waters with low visibility or obstacles between hubs. In addition, the equipment needed for such metrology is easily transportable.

The principle of an inertial unit is to calculate the relative position of the system in real time, from a known starting position. It contains an IMU (Inertial Measurement Unit) which consists of three gyroscopes and three accelerometers, two to two orthogonal (along the three axes of space). These sensors provide raw data of angular velocities and accelerations. These data are processed by a calculator that realizes the integration in real time to obtain attitudes, speeds and positions. The IMU is combined with a Kalman filter that uses sensors (accelerometers and gyroscopes) to provide corrections to the computed position.

2.1.6.Acoustic + INS

The biggest defect of the inertial method is its drift over time. Solutions must therefore be found to limit it in order to guarantee good results. A hybrid method combining inertial and acoustic metrology has been developed. It is more and more used and currently preferred since it offers a saving of time and a lot of redundancy, allowing a good quality control measures. The fact that acoustics do not drift is a feature that increases the performance of the INS.

These include the SPRINT systems (Subsea Precision Reference Inertial Navigation Technology) developed by Sonardyne and ComMet developed by iXBlue. These two systems are based on the same algorithm, SLAM (Simultaneous Location And Mapping). Such a system combines a very high quality inertial unit with an acoustic positioning system. The necessary equipment also includes transponders, a Doppler Velocity Log (DVL), a sound speed sensor and a pressure sensor.

2.1.7.Photogrammetry

Photogrammetry has recently been developed for underwater metrology. This involves getting a 3D model from two-dimensional photos. The technique is based on the principle of triangulation, that is to say that the points are determined by intersection of the beams. In theory, a minimum of two clichés is therefore necessary (intersection of two beams) to the reconstruction in three dimensions but, in practice, a larger number of photos is made in order to obtain an over determination of the data. However, a good metrology is not linked to a large number of clichés. Indeed, well positioned and good quality shots will be more appreciated than an overabundance that will lead to a much longer calculation time for a not necessarily better result. The best acquisition is to take photographs by turning around the structure to have maximum beam convergence. The software processing time is generally very long, unnecessary shots will increase the calculation time but will provide redundancy in the data. We must therefore be careful to find a good compromise between quantity of data and calculation time.

3. THE UNDERWATER LASER SCANNER

Different methods of underwater metrology have been developed. Lasergrammetry is a widely used technique for land operations. This part aims to study its adaptation under water.

Like terrestrial laser scanners, underwater scanners can be distinguished according to their measurement principle. There are currently three classes of terrestrial laser scanners: pulse scanners (time of flight), phase difference scanners, and triangulation scanners. Recent developments in underwater scanners are based solely on the principles of triangulation and flight time.

3.1. TRIANGULATION LASER SCANNER

Triangulation scanners were the first to be developed. There are currently several systems on the market. The 2GRobotics scanners (ULS-100, ULS-200 and ULS-500) seem to be the most widely used triangulation scanners in the oil world, but there are other systems such as the Fugro Seastiper.

The deployment of such systems is done on ROV or tripod. The scanner-object distance is calculated thanks to the geometry of the laser. Indeed, the distance d_{AB} between the transmitter and the receiver as well as the angles of projection and acquisition (α and β) of the laser beam are known, which allows deducing the distance between the scanner and the object.

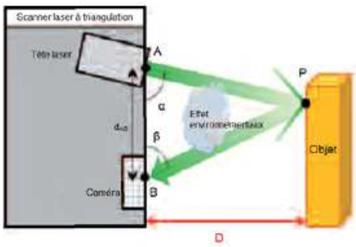

Fig.12. Principle of a triangulation laser scanner

A (simplified) expression of the scanner-object distance D is as follows:

$$D = d_{AB} \times \frac{sin(\beta)}{sin(\alpha + \beta)}$$

Although triangulation scanners provide very accurate results for small spans (less than 2m), as soon as the range becomes larger (greater than 2m), this system is less accurate than pulse scanners. Indeed, the geometrical configuration of the scanner prevents the triangulation scanners from being able to be developed for large ranges. This is because the beam captured by the scanner after the round trip undergoes many changes due to its divergence, the reflectance of the target or the formation of seawater.

3.2. PULSE LASER SCANNER

The biggest fault of triangulation scanners is the range of the laser. This is why scanners based on the principle of flight time have been developed. While some pulse scanners are in development, there is currently only one company offering this type of scanner. 3D@Depth has indeed developed the SL1 and SL2 scanners based on this principle. This type of scanner has the advantage of having a scope much less limited than the scanners used in the context of metrology operations described above.

As with triangulation scanners, scanners can be deployed on a tripod or ROV. For depths of more than 300m, deployment is performed only on ROV. SL1 and SL2 are said to be <camera scanners> because of their reduced field of vision. Camera scanners have a reduced angular field in vertical and horizontal. This is 30^0 x 30^0 for SL1 and SL2. These scanners are comparable to the first pulse terrestrial CT scanner that had a field of view of 40^0 x 40^0. It is possible to imagine that the development of underwater scanners will follow the same path, and that in the coming years, panoramic scanners (field of view of 360^0 in the horizontal plane and at least 180^0 in the vertical plane) will appear.

Figure 13 shows how the scanner is installed on the ROV. Thus, the SL1 is placed on a unit that can pivot in pan (<pan unit>), the latter being fixed on a support hooked to the ROV (<bracket>). The scanner sweeps windows of 30^0 x 30^0, this unit rotates to get a panoramic scan and scan both structures. Generally, the unit rotates by 20° between each acquisition in order to obtain a 10^0 overlay. Regarding the SL2, the unit can rotate in pan but also tilt, which allows to have a vertical field of 90^0. The SL1 cannot yet be deployed on such units because it is too large. Indeed, on the SL2, the box containing the optical part is separated from the electronics. Thanks to this, the optical part is smaller than the SL1 (34cm against 62cm for the SL1), which makes its possible integration on a unit that can tilt and therefore the vertical angular field of 90^0.

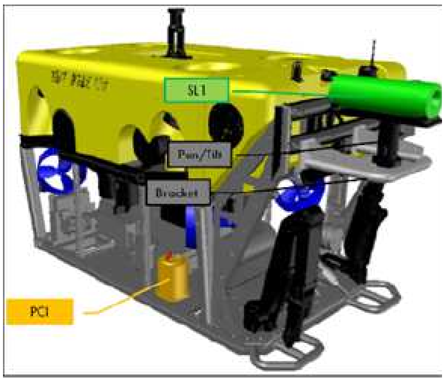

Fig.13. Installing the scanner and the different components on the ROV

An inclinometer is integrated within laser scanners developed by 3D@Depth. This inclinometer is a Minisense3 and provides the roll/pitch values of the scanner at the time of data acquisition with an accuracy of 0.04^0 to 1^0. It is used to <level> the scanner to get the true vertical of the place. Since there is no known reference to the bottom of the water, this inclinometer is the only way to obtain it.

A PCI (Power / Communications Interface) and a Multiplexer (MUX) are installed on the ROV to ensure communication with the scanner and its power supply. MUX is not essential to the system. Indeed, it is used only if the ROV is not able to provide Ethernet communications. The ROV is connected to the surface by a multifunction cable (called umbilical). This cable is used to power the ROV and communicate with it to drive operations.

Like terrestrial scanners, the development of submarine laser scanners based on the principle of phase difference would be a clear technological advance since it would represent a considerable time gain in terms of data acquisition. They may see the light of day in the years to come, but their integration into the underwater world causes many problems because the water may change the characteristics of the wave.

4. LASER SCANNER APPLICATIONS

The underwater laser scanner has many applications. This part is devoted initially to developing metrology but there are also other uses of this laser technology.

4.1. LASER METROLOGY

This protection consists in designing the parts and the mechanical assemblies in such a way as to limit the risks of corrosion.

Like photogrammetry, this technique relies heavily on the dimensional control of the structures, carried out on the ground, before their deployment in water. In fact, the dimensional controls of the structures are generally used to define the hub centre. It also depends mainly on the turbidity of the water. Indeed, we can measure only what we see.

The SL1 scanner is mainly deployed on ROV but can also be deployed on a tripod. If it is possible to scan both hubs from a single station, several stations are performed in order to obtain redundancy in the data obtained. This redundancy will make it possible to better model the useful parts on the structures.

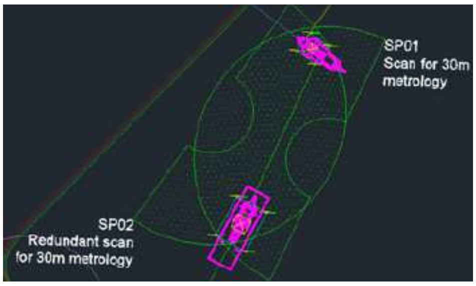

Fig.14. Positions of scans for short spans

When piping is too long (if the two hubs are not visible from a single station), it is important to have (spherical) targets on the seabed, to be able to consolidate the different scans. An additional station can be performed near the structures in order to obtain redundancy in the data.

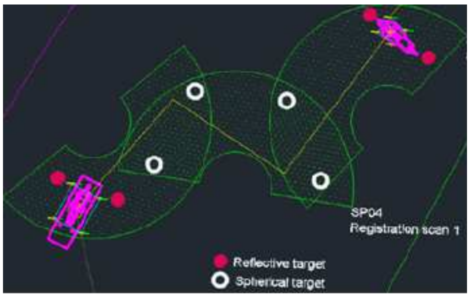

Fig.15. Positions of scans for long spans

The first step is to perform a series of tests, which will adjust the power of the laser and note the horizontal angles at which the hubs are located. The acquisition begins when the ROV is stable and the water is clear enough. 3D @ Depth has developed a series of applications for the acquisition, pre-processing and visualization of scans. The scanner sweeps on only 300, the panoramic unit makes it possible to rotate the scanner to make several sweeps that will cover the whole of the metrology. The data collected by the CTD probe is entered into the acquisition software before each scan in order for it to calculate the speed of light. The operations are repeated for each station and then the ROV is raised to the surface.

Then comes the processing of the data acquired - this treatment relies heavily on dimensional control of structures (DC, Dimensional Control). These DCs are drawings on which appear the distances between different particular points of the structure. The processing steps are the consolidation and modelling of geometric entities. Consolidation can be based on either point clouds (search for peer points) or target based. Once the clouds are consolidated, an intermediate step is to find the true vertical of the place using the values recorded by the panoramic unit. The search for the results is then carried out starting from the modelling of certain surfaces on the structures. These models are used initially to define hub centres as well as local benchmarks (for each structure), in which the attitudes will be expressed. In a second step, the models are used to extract the results.

The rendering consists of a report as well as a metrology drawing summarizing the different results. The processing steps should be detailed in the report so that the results monitoring team is well aware of all possible sources of errors and clarifications.

4.2. OTHER POSSIBLE APPLICATIONS OF THE LASER SCANNER

The laser scanner can be used for various other reasons in the underwater environment.

4.2.1. Field Mapping

3D models are widely used to visualize subsea installations and the seabed. Indeed, they make it possible to map the different structures and the seabed. Thus, thanks to the laser, a representation of the structures and the different elements as deployed is obtained. This allows the three-dimensional representation of the entire area (structures, electric cables, seabed ...). This modelling is useful for scheduling ROV operations and maintenance operations. Thus, we obtain the model <as grasped> which is the real representation. The data obtained is thus more useful than the <as drawn> model which would have been the ideal arrangement of the different elements. Figure 16 clearly shows the differences obtained, particularly in the position or orientation of the structures. For example, it can be seen that the true orientation of the structure surrounded in white is not the same as originally planned.

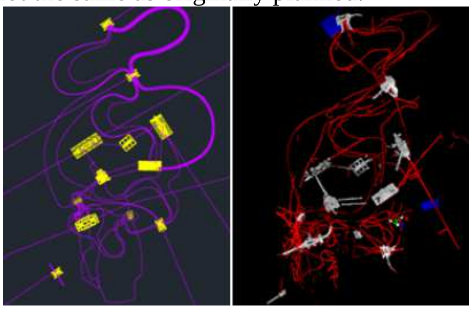

Fig.16. Differences between models: "as drawn" model on the left, "as captured" model on the right

Lasergrammetry can also be used to study seabed changes and analyze structures. Indeed, the modelling over time provides a follow-up of the installations and seabed. Such inspections make it possible to detect any problems related to structures and the damage they may suffer. As for metrology, targets can be used to consolidate scans, i.e. to assemble them to obtain more than a point cloud. Even if the consolidation can be done using specific points, the use of the spheres will make it more precise.

4.2.2. Acquisition of structures once installed

There are various cases in which it may be useful to scan subsea installations after their installations. One of the interests can be to follow the evolution of the structures. These can suffer some damage over time, and it is important to be able to evaluate these in order to intervene correctly if necessary. When missing some information on structures, the laser scanner appears a good solution. Indeed, if the different existing techniques such as inertial or acoustics do not allow to carry out dimensional control underwater, imaging systems such as lasergrammetry or photogrammetry are a solution that allows to intervene without have to touch the structure. The laser thus makes it possible to avoid having to stop production by bringing the structure back to the surface in order to take the necessary measures before putting it back on the seabed.

The phenomenon of subsidence can also be measured using this technology. The laser scanner makes it possible to observe the various movements of the seabed in elevation. The structure can also know certain movements over time and lasergrammetry represents a method to measure them. Lasergrammetry thus makes it possible to follow the temporal evolution of the underwater equipment of a petroleum field by great depth.

5. CONCLUDING REMARKS

Lasergrammetry is a very operational technique for the realization of underwater metrology. Through this paper, some points, for which laser technology can still make some progress, have been identified. Both in terms of system performance and in terms of processing the data obtained, this technique can be improved in the coming years.

In the first part, we noticed that the techniques currently used to perform metrology are having all certain advantages, but also some defects. The major disadvantage lies in the time of operations. Laser scanners represent a significant time saving because during a metrology, the ship is immobilized and cannot perform other operations.

Underwater lasergrammetry provides the three-dimensional models of the different structures and a complete mapping of the seabed, which makes it possible to avoid any additional displacements to make new measurements.

The beginnings of underwater lasergrammetry can be compared to those of terrestrial lasergrammetry. Indeed, like terrestrial scanners, two types of scanners have been developed for the moment, one based on the principle of triangulation, the other, pulse scanner. We can therefore imagine that the development of underwater scanners will follow the same path, and that in the coming years, panoramic scanners will emerge.

Similarly, like terrestrial scanners, the underwater development of phase difference laser scanners would be a clear technological advance and would represent a considerable time gain in terms of data acquisition. It would be interesting to study their possible integration in the underwater environment.

As expected, data processing is the most complex part of this technique. Indeed, the choices made during the treatments can have their importance and a bad interpretation can very quickly influence the results. This new technology requires a lot of vigilance and analysis. Treatments should therefore be accompanied by QC procedures to evaluate the accuracy of the final rendering.

At the moment, only one company is developing laser pulse scanners (or time-of-flight) and some companies are marketing scanners based on the principle of triangulation. We can imagine that in the future other companies will come to compete with them. Currently, some developments are underway to associate the laser system with an inertial unit. It will therefore be possible to perform laser surveys using an autonomous vehicle (AUV) that can <fly over> the study area, while scanning. This is the mobile laser-radar, 3D @ Depth is currently studying a similar system that would associate an inertial unit to the laser scanner.

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