HIGH PRESSURE MOULDING TECHNOLOGY

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Abstract: The Optical submarine cables are insulated with a polyethylene (PE) layer. When a cable joint is required, the electrical insulation and water tightness functions are usually provided by a polyethylene over moulding, especially when high dielectric insulation performance is required.

The main technical constraints of this operation are to maintain the minimum wall thickness of the PE sheath to guarantee the electrical performances and to avoid or minimize the defaults that can appear during the process, such as pollution (metallic or not), voids or bubbles which may lower its electrical performances. The moulding operation shall be as well designed to minimise the overall jointing time in order to be the most appropriate tool whatever the situation or configuration is in operation. Several technologies exist in the field depending on the application (on or off shore) and depending on the targeted performances (repeatered or un-repeatered system).

The paper therefore concentrates on the various PE reinstatement technologies and compares them to an alternative moulding technology based on a "high pressure" moulding technology.

1 INTRODUCTION

One of the most critical steps part of the jointing operations conducted during submarine cables installation or maintenance is the reinstatement of the insulation layer, for the two following main reasons:

- First, the moulding operation is on the critical path of the joint construction. At this phase both ends of the cable have to be anchored, fibre spliced and the joint closed; it is not possible to anticipate this phase or to make in parallel with other operations
- Second, the joint insulation reinstatement ensures the electrical functionality, which is a critical feature. This is checked after each moulding, the moulded jointing box through X-Rays inspection to verify that no defects that could affect the joint electrical reliability are present.

Therefore, the moulding operation needs to be as quick and reliable as possible.

In order to answer to these constraints Alcatel developed, qualified and introduced in 1993 for their cable products a moulding machine based on a high pressure technique.

After 14 years of experience with this type of equipment, both in factory and on the ships during cable installation, we now intend to expand its use to the marine maintenance operations.

Following a comparison with existing techniques, this paper will present the possible evolution of such technology and then evaluate the impact on the marine installation and maintenance operations.

2 STANDARD INSULATION PROCESS

Today two types of processes exist and are commonly used depending on the submarine system type, namely Repeatered or Un-Repeatered.

2.1 Heat-shrink sleeve insulation

An un-repeatered system by definition does not require that the over sheath reinstatement be for a high voltage insulation, but only to guarantee the resistance to water ingress and provide an insulation resistance suitable for the use of electroding technique. Then for the cables used on such systems, the insulation reinstatement is made by application of heat-shrink sleeves and sometimes with a polyethylene preform.

Depending on the heat-shrink sleeve type, it may be necessary to add an adhesive to improve the bonding on the polyethylene of the cable.

The application of a heat-shrink sleeve is mainly made by using flame or heat gun and depends strongly on the experience and the dexterity of the jointer.

Such method remains easy and quick but remains difficult to control.

2.2 Moulding process insulation

For the repeatered systems, insulation reinstatement must allow the joint to sustain a high voltage level of at least 10 kV for 25 years. As a result the heat-shrink solution cannot be applied since it is suitable only up to 500 V.

The solution is then to re-build the insulation layer over the metallic jointing box in applying a layer of polyethylene (PE), a similar material to the one used on the cable. The operation procedure for the standard technique consists in first sliding a PE sleeve over the metallic sleeve of the jointing box (JB) and then using a

moulding machine to fill with injectant PE the remaining volume in between PE sheath shoulder made on the cable and the edge of the PE sleeve (See figure 1).

The principles of this standard moulding technique exist since 20 years and are based on a simple extrusion process, used to fill the moulding cavity with the melted PE.

In order to avoid entrapped air to create bubbles during the moulding process, it is necessary to drain the mould cavity by allowing the injected PE in excess to exit at the opposite side of the injection point.

This configuration allows the Injected PE to flow through the mould cavity (See figure 1).

The amount of injected PE when passing over the cable PE pre-heated shoulder can draw along adhesive copolymer layer or other insulation layers to the drain side; this is called the “wash up effect”.

The wash up effect may induce un-controlled and risky amalgamation area.

To prevent this wash up effect, a PE cable end shoulder protection was designed (See figure 1).

The cable ends are pre-heated by thermal conduction to 200°C via the moulding cavity. The low thermal conduction of the PE as insulating brings as a main drawback an extension of the pre-heating phase.

Once the PE filling in the mould cavity is complete it is necessary to cool down the mould cavity to an acceptable temperature allowing the injected PE to harden.

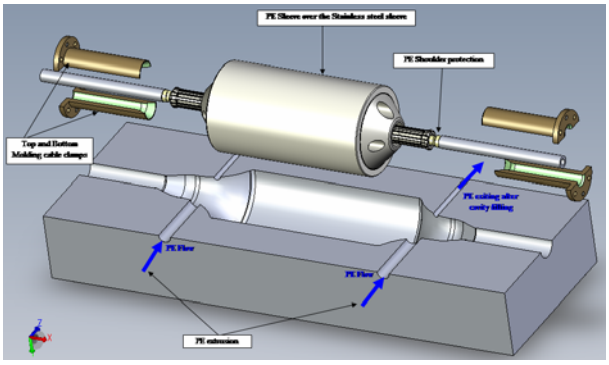

Figure 1

The overall time required for such process is about 2.5 hours (See table 1).

The additional operation to protect the PE shoulder and to slide the PE sleeve requires respectively 15 minutes per cable end and 10 minutes times.

4- THE HIGH PRESSURE MOLDING MACHINE

The high pressure moulding technology has been qualified and introduced in 1993 by Alcatel for its own joint box design, for use in the factory and during installation.

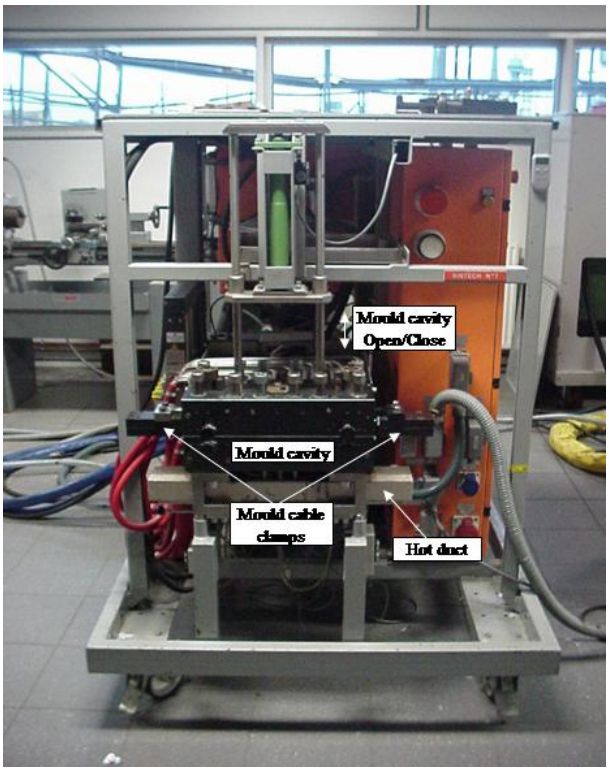

Figure 2

Extrusion and Injection

The main differentiator of this machine is to combine the standard extrusion process with an injection under high pressure, using an hydraulic jack to push the screw to compact the material into the mould cavity.

The injectant PE is thus maintained under high pressure (between 250 and 300 bars), avoiding the formation of void or bubbles that may be generated by the material shrinkage during the cooling process.

The extruder is as well designed in order to dramatically reduce the mould cavity filling time (1.20 mn).

In addition the equipment and the process allow for the cooling phase to start simultaneously with the injection phase and are capable of achieving a total cooling time of less than 10 minutes.

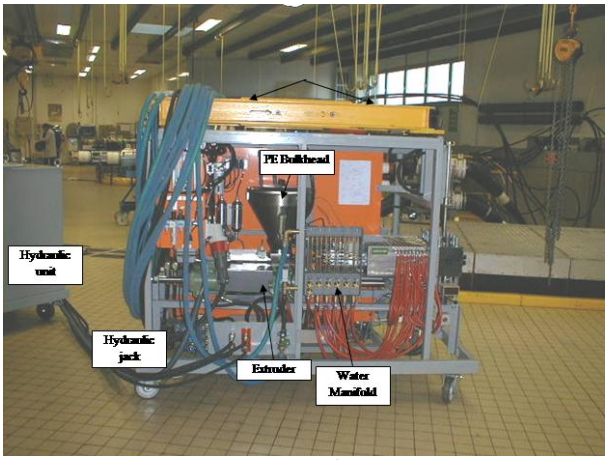

Figure 3

Pre-Heating

The other main improvement brought by this equipment is on the pre-heating of the cable ends. The cable ends are softened by blowing hot air on the PE cable interface (corresponding to the amalgamation area), prepared in the shape of a cone.

This forced convection method is much faster than the thermal conduction one. It allows to reduce significantly the mould temperature (100°C instead of 200°C) and then reduce again the cooling phase.

The mould temperature is set at the level of the standard moulding PE melt point, which is not required at the cable ends for the pre-heating. Thanks to this advantage (low mould temperature) the moulding product is free of residual stress which further improves the high voltage performances. This operation is under full control and not dependent on the outside temperature.

Purging

After the hot air pre-heating, the mould cavity is filled from both sides of the cavity and then the junction is made in the middle of the joint in which an annular purging hole guarantees air draining from the mould cavity (See figure 4). The annular purging is the area in which both injectant PE flows reunite, with no visible amalgamation area, as can be observed on microtome slices.

Annular injection

The most innovative feature of this PE injection technology remains however its annular injection, located just in the middle of the cone-shaped PE shoulder.

The mould cavity is filled symmetrically on all directions with a balanced pressure, which ensures the centering of the joint in the mould without the necessity to use a PE sleeve (See figure 4).

The annular injection associated with the high pressure ensures also an amalgamation of both cable and moulding PE distributed all around the interface uniformly.

As a result the wash up phenomenon is very limited since the volume required to fill the interface is well balanced and very small. The PE shoulder protection required in the standard technique is not required with this high pressure machine.

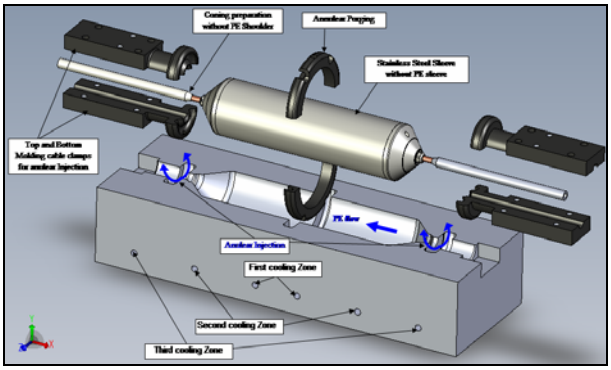

Figure 4

The total time to perform the moulding operation is around 20 minutes from the time when the joint is placed in the mould cavity up to its removal (see figure 5).

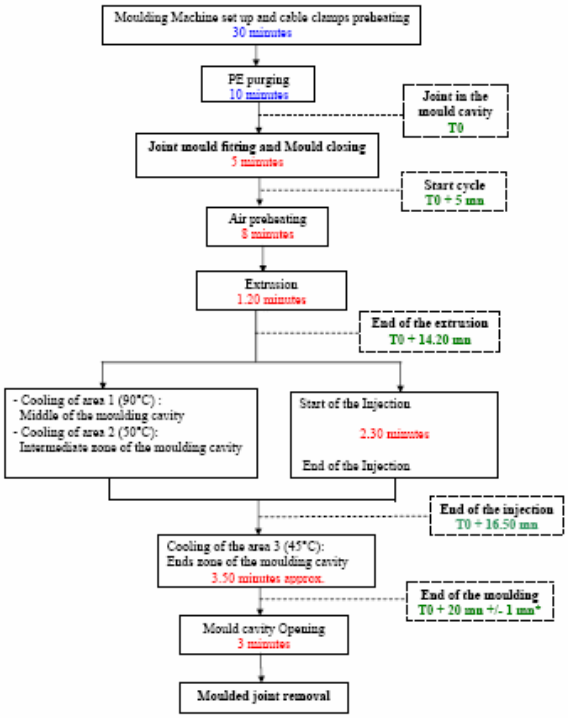

Figure 5

The process adaptation for another cable design is mainly:

- The cable clamp design to adapt the mould cavity to the cable size (see figure 4)
- The pre-heating which may be different depending on the PE cable characteristics (Melt Flow Index (MFI) and the Melt Temperature).

3 EXPERIENCE

3.1 Qualification

The high pressure moulding machine has been tested and processes qualified for different cable designs.

Cables with the following features have been qualified with this technique:

- outer insulation sheath diameter from 14 to 22 mm
- PE wall thickness from 3 to 5.5 mm.
- High, Medium and Low Linear density insulating Pe
- With one or several PE layers
- With or without an adhesive layer

Qualifications were conducted according to the following program:

- Samples: 6 moulding and 2 re-moulding joints made at the limits of the process (high and low temperature)
- X-Ray inspection
- High Voltage test up to 200 kV during 1 hour
- Elongation and inspection test on amalgamation area
- Heat-shrink test

Several interconnection joints made with cables from different sizes and construction were as well successfully submitted to the qualification program, demonstrating that the moulding process is not affected by cables mismatch.

4 OPERATIONAL

After more than 10 years of operation both in factory and aboard installation ships, the high pressure molding process and equipment have shown a very high degree of reliability. Recently a process study conducted on more than 1000 joints sampling showed a yield to be better than 95%, confirming that this technique is a mature and proven technology.

These results have been obtained as part of cable installation on various cable ships, ranging from a barge to state of the art cable ships, and under various environmental (temperature and humidity) conditions.

5 THE HIGH PRESSURE MOLDING MACHINE VERSUS OTHER TECHNOLOGY

The high pressure moulding machine has been as well benchmarked against the standard equipment, to list the advantages and drawbacks of each technology.

In order to be comparable, the study has been focused only on the moulding techniques.

The study focused on two aspects: moulding duration and technology.

Timing Comparison

Criteria	HP moulding machine	Standard moulding machine
Assembly of the moulding press	Not applicable	20minutesAssembly around the joint
Set up of the machine – pre-heating - purging	40 minutes made without the joint in the cavity	30 minutes with the joint in the cavity
Joint placed in the mould	5 min	Already made
Hot air pre-heating	8 min	Not applicable
Extrusion	1.20 min	27 min
Injection	2.30 min	Not applicable
Cooling	3.50 min	56 min
Joint removal	3 min	15 min
Total with joint	**23 min**	**148 min**

Table 1

Technical Comparison

Characteristics / performances	HP moulding machine	Common moulding machine
PE sleeve required	No	Yes
Peek or Copper seal	No	Yes
Cable adaptation	14 to 26 mm	14 to 25 mm
Re-moulding operation	Yes	Yes
PE cable density	L –M– H	L –M– H
Amalgamation areas	2	4
Temperature inside the joint during the process	<100°C	130°C
Compatible with marine environment	Yes	Yes
Equipment assembly	No	Yes
Transportable	Yes	Yes

Table 2

Amalgamation area: This is the zone in which the welding between the Injectant PE and the Cable PE and the PE sleeve (for the standard machine) is made. This area is critical since the welding is one of the key points to make a successful and reliable moulding – the HP moulding machine requiring only two zones limits the risk of non conformity.

Cable diameter size: For both machines, the adaptation of the cable diameter is made with the moulding clamps designed and used for each cable.

The high pressure has been designed to be the most compact possible and then all parts are already assembled and the machine is ready for the operation.

The standard molding machine requires to be assembled around the joint, which increases the risk of equipment breakdowns.

6 DISCUSSION AND FURTHER WORK

After several years of use and considering all the benefits of this technique, ASN decided to offer an extension of the use of the High Pressure moulding machine to the marine maintenance applications and then to adapt the moulding cavity to the Universal Joint.

Corresponding development was started in 2003, and is now completed allowing proposing in a first step the use of this machine on several cable designs covering about 80% of installed cables worldwide.

The next evolution of the machine, depending on market needs, is to re-engineer the equipment to reduce its size and weight.

In parallel and in a case per case basis, other cable designs may be qualified upon request.

7 CONCLUSION

Continuous traffic growth and pressure from system owners further emphasize the need to improve and to reduce the cable repair cost and time.

During Marine Operations, jointing is part of the critical path and its completion is one of the keys for a fast repair.

Jointing time analysis conducted logically identified the moulding as one of the required axis of improvement, for an optimised marine operation.

The High pressure moulding machine answers to a significant extent to this requirement, reducing the moulding time by a factor 6.

The high pressure machine is one of the tool which will give a significant improvement on quality and productivity.

8 REFERENCES

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