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THHN CABLES AND CABLES WITH PA JACKETING

The THHN Cable (Thermoplastic High Heat Resistant Nylon) is a kind of cable with insulation PVC and PA6 jacketing. The cable can be produced by:

- coextrusion process;
- tandem process.

THHN CABLE PRODUCTION		
CO-EXTRUSION	**TANDEM**	
Triple layer head PVC+Nylon	Dual layer Head for PVC	PA Jacketing Head

1. TANDEM PROCESS

The line is composed by one crosshead for PVC insulation and another one for nylon jacketing. The cable is made by one step process.

The marking is made directly on hot PVC cable surface and immediately before applying the nylon layer. In this way the marking is more durable being under the nylon. After that, marking is directly going inside the single layer head for nylon jacketing.

2. PROCESSING FACTORS

An important role is played by:

- the distance between the PVC head and nylon head;
- the distance between nylon head and cooling through;
- the temperature of the water into the first part of the cooling through;
- heads and tools shape and dimensions;
- other factors which will not be faced on this paper.

3. DISTANCE BETWEEN PVC AND NYLON HEADS

The distance acts on the temperature of the PVC cable surface before applying the nylon layer. In turn, the temperature of the PVC cable influences:

- the marking process quality;
- adhesion of the nylon layer on the PVC surface.

Too short distance (according to line speed defined) generate higher PVC temperature and consequently overheating of the marking wheels. After a while the PVC can stick on the wheels. The wheels must be designed in order to be cooled down by air flowing. Anyway, as we will explain later, there is another method to reduce the temperature of PVC cable for marking process without acting on the nylon adhesion.
Too long distance can reduce too much the PVC cable temperature, which helps the marking process but reduce the nylon adhesion BY creating the horse-collar or ring effect.

An excessive temperature the marking wheels causes defect on the marking because the PVC sticks on the wheel. The higher is the line speed the higher is the over-heating effect of the marking wheel.

In order to increase the line speed reducing at the same time the overheating, it is necessary to reduce the temperature of the PVC surface. The cooling of the PVC is needed in order to perform the marking process without acting on the adherence between PVC and nylon.

3.1 PVC SURFACE COOLING

The cooling of the PVC surface can be done by:

1) removing the water from the cable by a drying process;
2) nebulization system.

WATER COOLING

Once completed the passage in the PVC head, the cable is cooled down by water into a short cooling through. The cable must therfore be accurately dried before getting in the nylon head. This process does not guarantee high line-speed and repeatability of the process due to the difficulty on the drying process.

NEBULIZATION SYSTEM
The outer surface of the hot PVC cable is cooled down by nebulized air with particles of water. The small particles of water, touching the PVC surface, reduce the surface temperature and consequently the water evaporates. This guarantees higher line speed due to the regulation of the quantity of water into the air, as well as the air pressure.

The distance between the PVC head and the nylon head should be the minimum to allow the water evaporation before getting into the nylon head.

3.2 DISTANCE BETWEEN NYLON HEAD AND COOLING THROUGH

The distance acts on the crystallinity of the nylon layer in terms of grade and dimension of crystals. Among other things, this acts on:

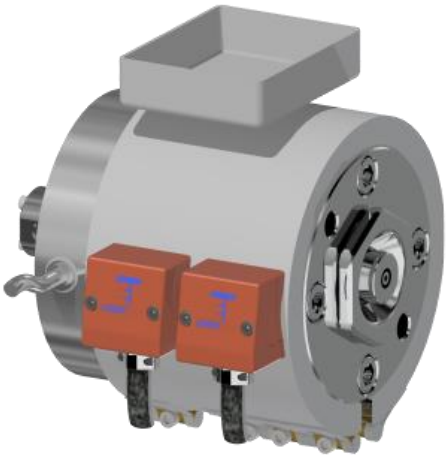
- transparency of the jacketing;
- shrinkage of the nylon layer;
- adhesion around the PVC cable;
- elongation;
- tensile strength.

3.3 TEMPERATURE OF THE WATER INTO THE COOLING THROUGH

The water temperature influences:

- the nylon crystallinity;
- adhesion of the nylon layer on the PVC surface;
- surface aspect;
- elongation;
- tensile strength.

4. TOOLS



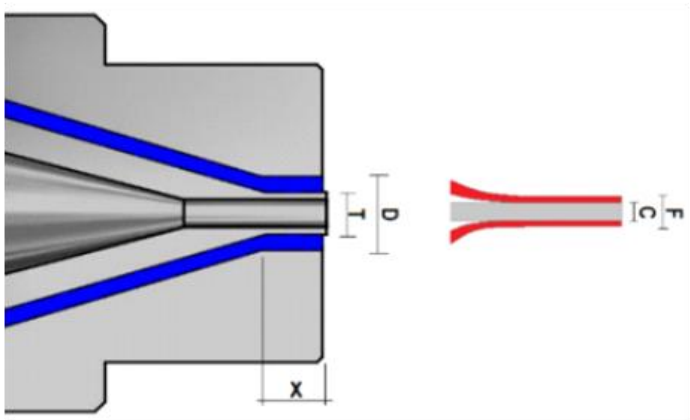
4.1 INSULATION
Compression tools can be used. The die diameter **D** can be calculated as below described:

$D = C - k$
$0.17 < k^{*} < 0$

D: Die Diameter [mm];
C: Final Cable Diameter [mm];
k: Correcting Factor [mm].

****K** depends on cable and conductor diameter, type of compound, line speed, adhesion, etc.*

4.2 NYLON JACKETING
The head must have a proper and efficient flow distributor design in order to guarantee the correct nylon flowing and high cable concentricity.



The head should allow the fine centering if fine concentricity adjustment is required.
The Polyamide must be applied using tube tools.

$DDR = C_2/ C_1 = S_1/S_2 = [D^2 - T^2] / [F^2 - C^2]$
DRB = D*C/F*T

For tools calculation it must be considered that:

- the inlet cable is HOT PVC;
- the PVC cable must not touch the tip of the nylon head due to the higher temperature.

The tube tip must have a hole diameter big enough, avoiding the contact with PVC. The die must be calculated considering the proper DDR valued.

Vacuum must be correctly applied even according to the DDR chosen and the max acceptable length of the nylon cone.

Considering that the PA is applied on the hot PVC cable and the materials have their own shrinkage, the die diameter must be calculated considering the hot PVC diameter and the hot nylon thickness.

5. EXAMPLE OF CALCULATION (PVC+PA in Tandem Process)

Conductor: 12 AWG
Copper Diameter: 2.05 mm
PVC Thickness: 0.38 – 0.40 mm
Cold Insulation PVC Diameter: 2.81 – 2.85 mm
Nylon Thickness: 0.10 mm

Final Cold Diameter: 3.01 – 3.05 mm

The next step is to define the value of:
- hot PVC cable diameter;
- hot cable diameter with nylon jacketing.

The diameter can be known by using the diameter gauge or by theoretical calculation.

DIAMETER CALCULATION (Without Diameter Gauge)

Hot Insulation PVC Diameter: 2.89 – 2.94 mm
Final Hot Diameter: 3.12 – 3.16 mm

EXAMPLE OF TOOLS CALCULATION (Hot Condition)

DDR: 7.5 (in Hot Condition)
DRB: 1.012 (In Hot Condition)
Die Diameter: 7.65 mm
Outer Tip Diameter: 7.05 mm
Inner Tip Diameter: 4.60 – 5.00 mm
Nylon Elongation: 85-87 %

The DDR can be chosen between 3 and 20. **The value depends on PA type, cable dimension, polyamide thickness, line speed.**

High DDR is normally applied for higher line speed and small cable.

According to cable diameter, too high DDR can cause:
- oval surface (not round);
- uneven nylon thickness distribution;
- nylon layer out of center;
- too long nylon cone.

Too low DDR can generate low nylon adhesion on the PVC surface, low quality of surface aspect, low transparency, etc.