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PVC-O Fittings

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Abstract

MOLECOR introduces for the first time in North America, PVC-O FITTINGS.

One of the missions of technological companies is to adapt and adopt market demands. Molecor is definitely doing so by developing its technology towards big diameters and high pressures, now being available DN 30" (811,8 mm) and 365 psi (25 bar), and also entering PVC-O FITTINGS for the first time.

The first fittings ever done on PVC-O material were presented during last K show in 2013: 45º and 90º elbows, couplers, repairing couplers and double socket redures. The prototype was validated during 2013 and along 2014 the industrial development will be ready. The PVC-O fittings will be available for MOLECOR licensees at the beginning of 2015, including elbows, couplers and T´s. Currently, the materials used to manufacture fittings for pipelines usually are PVC-U or Ductile Iron, as there is no supplier of PVC-O fittings so far in the world. The market possibilities for this new product line are very promising.

The process to manufacture PVC-O FITTINGS is based on: air based system, 100% automatic process, and the highest orientation degree that guarantee the best mechanical properties of the fittings. With this new product new challenges are presented from a product design perspective.

INTRODUCTION

PVC-O pipes were developed almost 40 years ago in the UK. The mechanical characteristics of these pipes were quickly recognized due to their great impact and fatigue resistance, elasticity, no crack propagation and tensile strength among others.

During the first three decades of life of this product, there were some limitations such us standardization, manufacturing process, range of products and industrial efficiency. A deeper analysis of the technology and the product can be found in Muñoz´s (1) and Arena´s (2) papers during previous Plastics Pipes.

Molecor came to the industry in 2006, and during these few years (eight now) has managed to create a new process to manufacture PVC-O pipes overcoming previous challenges, regarding efficiency and manufacturing processes and has participated very actively in the creation of new standards throughout the world, and in the continuous update of the current standards. Please see Figure 1 with a summary of the most representative PVC-O standards in the world, and its main parameters. Here it is worth to highlight the last update of the International Standard, ISO 16422 (3) which took place this year 2014 and in which the product range has been extended from the previous maximum DN 630 mm, in the 2006 edition, to a maximum diameter of DN 1000 mm, reflecting the market trend of growing into big diameters.

HYDRAULIC DESIGN

Standard	Class	σ_s	Cs	HDB (psi)	(MPa)	MRS (MPa)
ISO 16422:2014 UNE-ISO 16422 BS-ISO 16422 SANS 16422	315	20-16	1,6-2			31,5
	355	22-18	1,6-2			35,5
	400	25-20	1,6-2			40
	450	32-28-23	1,4-1,6-2			45
	500	36-32-25	1,4-1,6-2			50
AS/NZS 4441:2008	315	20				31,5
	355	22				35,5
	400	25	1,6			40
	450	28				45
	500	32				50
ASTM 1483-12 NTC 5425	PVCO 1131	21,7 (3.150 psi)	2	6.040	41,62	39,9 (stim.)
	PVCO 1135	24,5 (3.550 psi)	2	6.810	46,92	42,6 (stim.)
AWWA C909-09 CSA 137.3.1-13		24,48 (3.550 psi)	2	7.100	48,95	42,6 (stim.)
ABNT NBR 15750	400	25	1,6			40
	450	28				45
AFNOR T 54-948	355	22				35,5
	400	25	1,6			40
	450	36				45
	500	40	1,25			50

Figure 1: Summary of most representative PVC-O standards in the world and its main parameters

All this without forgetting the market demands that focused on growing in size and pressures, nowadays reaching PVC-O pipes DN 800 mm or 30" and up to PN 25 bar (365 psi) or 305 psi according to North American standards.

Reaching this level of development and state of the art has been possible thanks to the continuous investment in R&D. But even though the range of products has been indeed enlarged and the process improved, there has been a continuous question throughout all presentations around the world: "what about the fittings?"

Until today there were no PVC-O fittings in the world and PVC-O lines had to be installed with either PVC-U fittings or ductile iron fittings, being most common ductile iron fittings due to the range of diameters and pressures used with this product. This will change very shortly, having now the possibility of offering a single plastic solution for water pipe lines 100% in PVC-O material.

CHALLENGES

During the development of this new product the main challenge to face was to apply successfully our previous knowledge of Molecular Orientation to pipes, to fittings and therefore to a new and changing geometry.

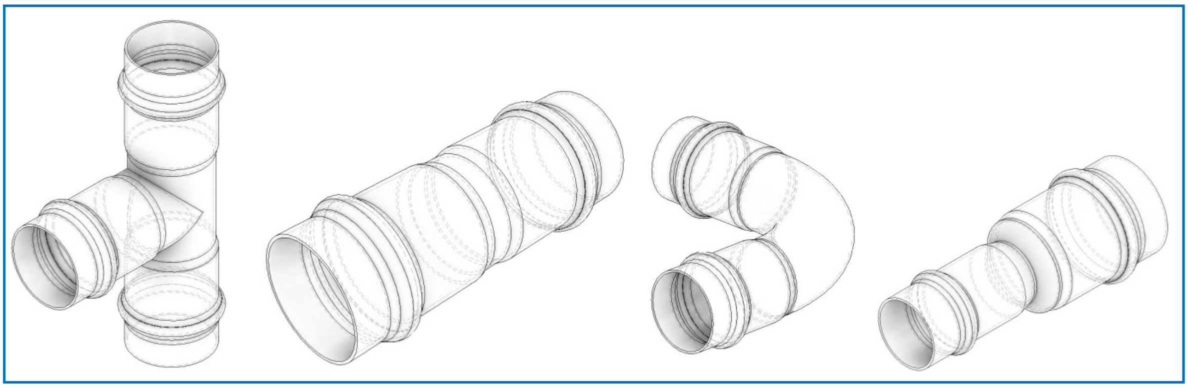

Figure 2: Different geometries of the developed fittings

The second challenge was the lack of standardization till today regarding plastic fittings and their application. This gap has already been detected by the international standards and there is a standard under development by the Technical Committee 138, under the International Standard Organization, and which already takes into account PVC-O fittings and its special features: ISO TC 138/SC 4/WG1 N1203 (4).

Because of the changing geometry a thorough study was conducted in order to achieve the correct design parameters that led us to a successful product. Schematically the process was as shown in Figure 3.

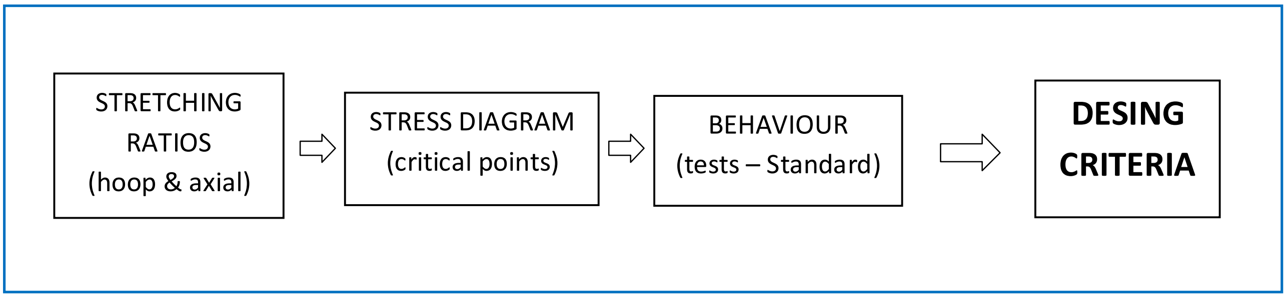

Figure 3: Process followed to get to the design criteria

CASE STUDY: 90º ELBOW

The previous criteria (Figure 3) are applied to the geometry given by a 90º elbow.

STRETCHING RATIOS

First of all, it is necessary to study the different stretches that will take part in the hoop and in the axial direction of the fitting. In order to do so we proceed to take measures in several fittings previously to its orientation process, as shown in Figure 4.

Figure 4: Measures taken in 90º elbows

After the collection of measures on at least 20 samples, the stretches obtained in the hoop and in the axial direction were as per Figure 5.

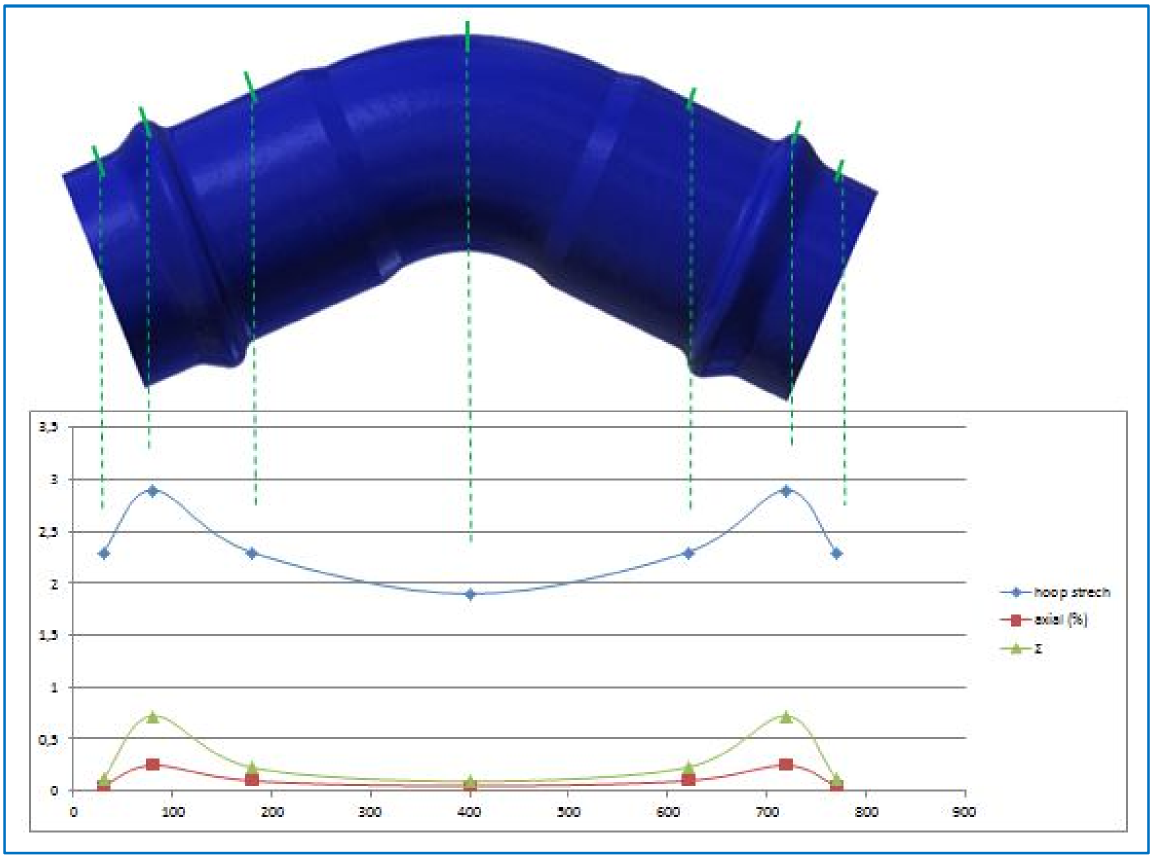

Figure 5: Hoop and Axial Stretch in 90º elbow

From the hoop and the axial direction we obtain ∑ being:

$$\sum = \Sigma_{hoop} \times \Sigma_{axial}$$

With the ∑ we obtain key parameters for the design of the pipe. Figure 6 shows graphically the result of both stretches for the product.

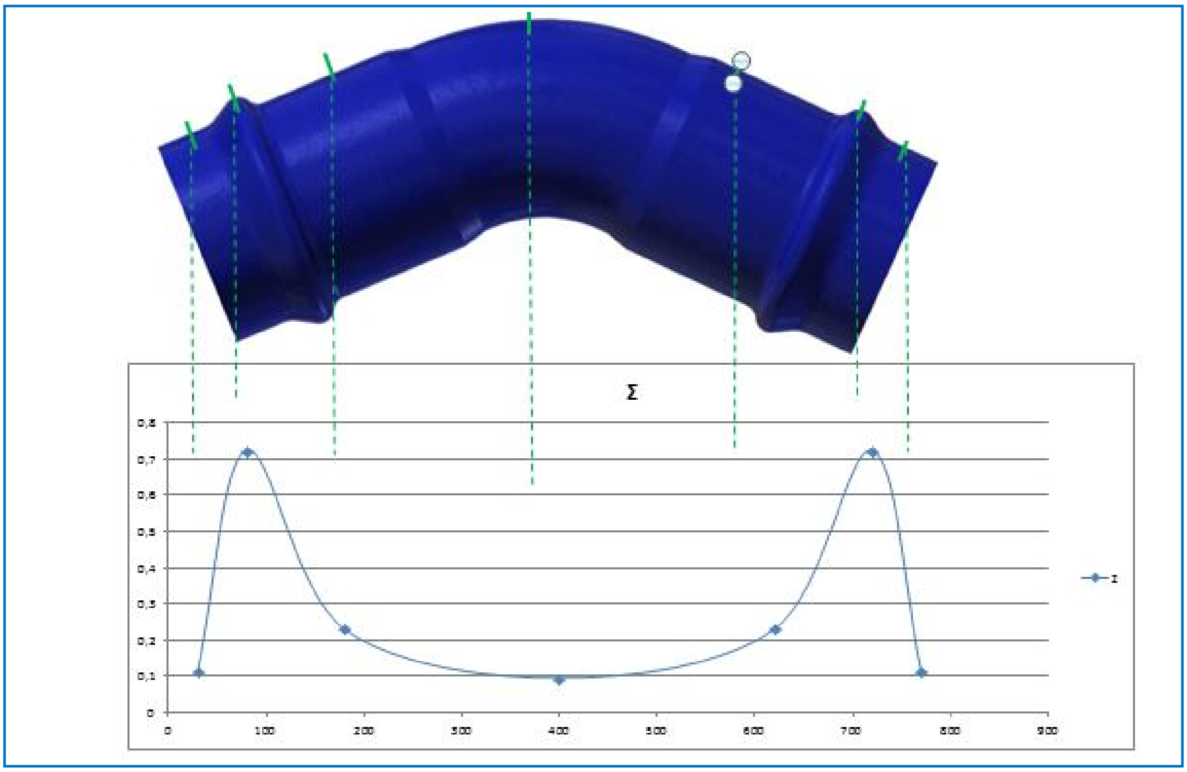

Figure 6: Stretch Ratio taken into account for the design

Regarding the stretches it is also important to have into account the different behaviors of the generatrix of the fitting as per Figure 7.

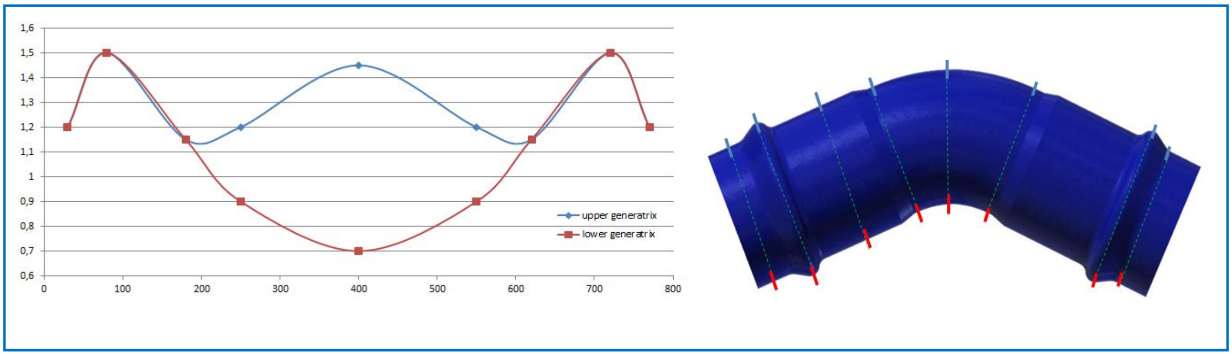

Figure 7: Stretch Ratio in upper and lower generatrix from a 90º elbow

A study of the hoop stretch achieved in different sections it is also very interesting to obtain further information regarding the behavior of the fittings as per Figure 8.

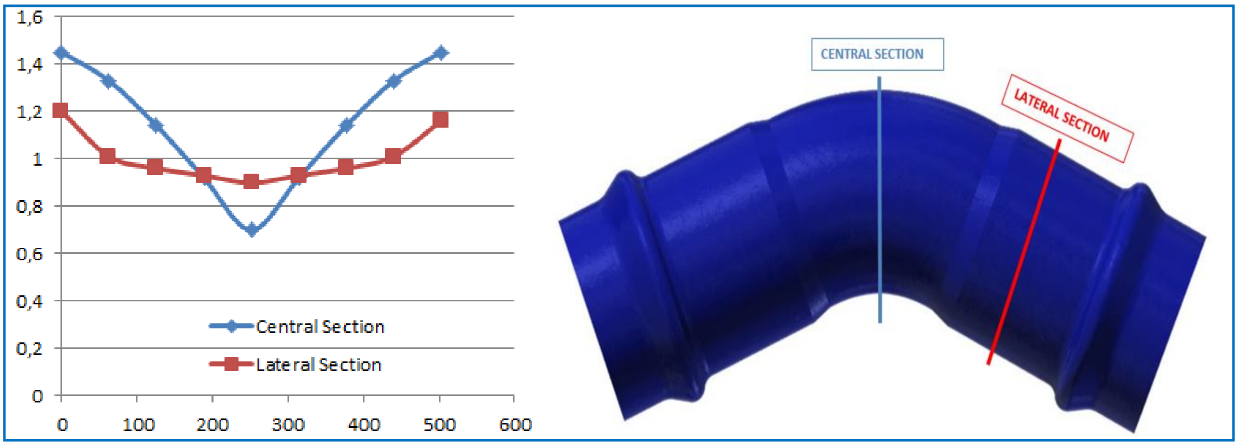

Figure 8: Hoop stretch in different sections of the 90º elbow

After the study of the axial and hoop stretch along the geometry of the 90º elbow the conclusion is that there is a negative effect of the axial stretch on the mechanical properties given by the hoop stretch due to the particularities of the geometry. The axial stretch and its degree is a parameter to be watched carefully during the process.

STRESS DIAGRAM

It is required to have simulations of the stress achieved by the 90º elbow under different stress conditions that can simulate what could happen in the worst case scenarios in the lifetime of the fitting. In order to do so there is an analysis by FEM.

Different restrictions are defined for the study as per Figure 9, with or without friction, restricted in one side, in both, in the middle, etc.

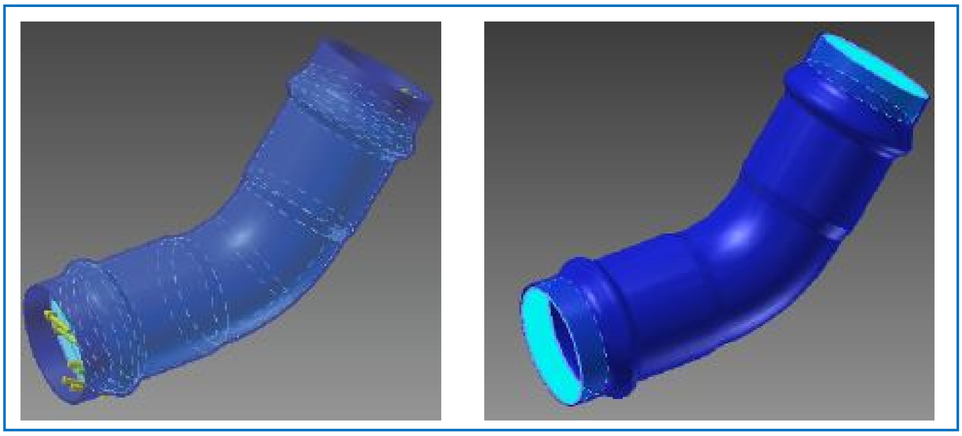

Figure 9: Different conditions from which to start the FEM analysis, pressure inside PN 16 bar and with lateral ends restricted.

A sample of this analysis is Figure 10 analyzing the deformations and Figure 11 analyzing the tension on axis XX and opposite.

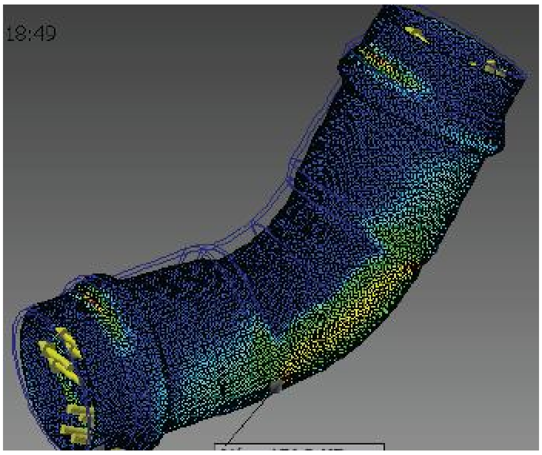

Figure 10

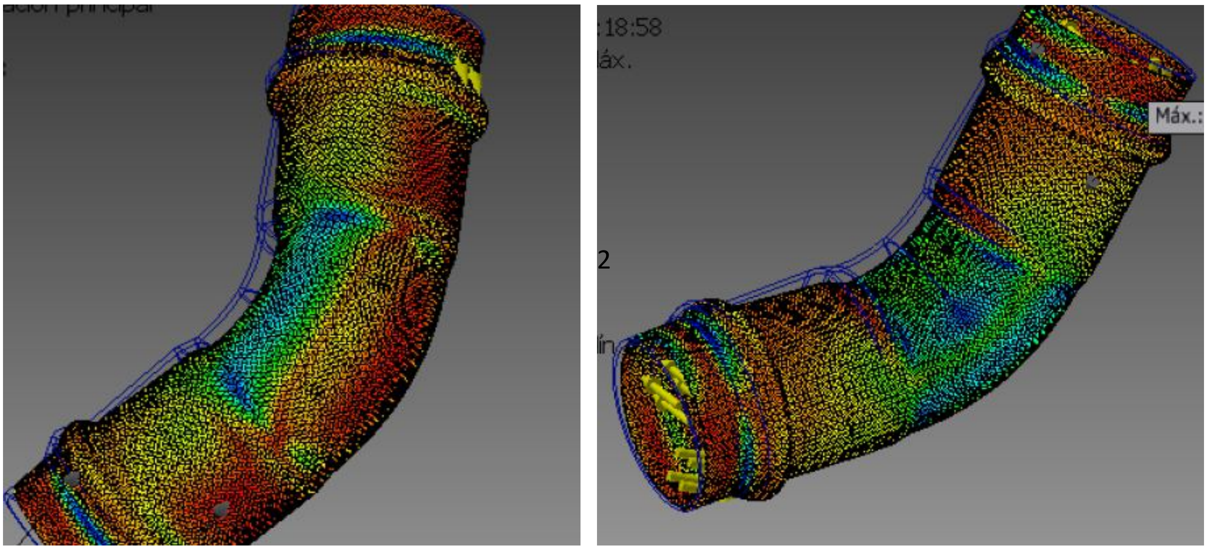

Figure 11

BEHAVIOUR-TESTS

The fittings developed are tested mechanically under the conditions specified on the provisional standard for plastic fittings ISO TC 138/SC 4/WG1 N1203 (4).

Some of these tests are regarding leak tightness as those in Table 1.

Time	Temperature (ºC)	Pressure (bar)	Test
1h	20	1,5PN	Leak tightness
1000 h	20	1,2PN	Leak tightness
1h	23	1,5PN	Leak tightness curvatura R=20dn
1h	20	-0,8	Vacuum
90 min	23	s/ 13845	Leak tightness with angular deviation and deformation

Table 1: Some specific tests on ISO TC 138/SC 4/WG1 N203 (4)

CONCLUSIONS

In order to correctly design fittings made of PVC-O it is fundamental to reach a final product complying with the mechanical properties and therefore to maintain the greatest orientation degree already obtained in pipes (CLASS 500).

It is necessary to have into account parameters not considered before in the plain pipe, because of the complex geometry that fittings bring to the table.

An analysis of the stretching ratios (hoop and axial) along the length and in different sections of the fitting is required. After a thorough analysis the conclusion is that the effect of the axial stretch has a negative impact on the mechanical properties enhanced by the hoop stretch. The axial stretch must be controlled during the process.

PVC-O fittings will be tested according the standard ISO TC 138/SC 4/WG1 N1203 (4) which is under development and already refers to PVC-O fittings for the first time.

Molecular Orientation applied to pipes, continue bringing new solutions to have complete PVC-O pipelines, being PVC-O fittings available during next year 2015.

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