Textile injection process characterization by means of a spiral mould

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Abstract

New developments are being carried out within the injection moulding field, such as gas injection, bi-injection, co-injection, sequential injection, compression injection or textile injection processes. These techniques require new developments as they highly modify design and process conditions. In this work, the influence over the plastic material flow of the introduction of different film textiles into the mould is measured. A specific measurement system consisting of a monitorized spiral mould with pressure sensors has been used to measure the influence of different tissues over the mould pressures. As an application of this measurement system, a viscous model is generated to characterize the rheological behaviour of the thermoplastic and textile joint. The viscous model obtained is applied on a conventional CAE tool for the simulation of textile injection pressure results for the different film textiles analyzed.

Keywords: overmoulding; textile injection; spiral mould; process characterization; viscosity; injection pressure.

1. Introduction.

Plastic injection parts obtained by a conventional injection process can achieve smooth or textured surface finishes, but in many cases, these types of surface finishes are not enough. Strong competition and new requirements of the market demand plastic injection parts with different surface finishes. Previously, superficial finish was given to the parts by subsequent injection processes. Nowadays, many non-conventional surface finishes can be obtained during the injection process by means of over injection processes. Within the over injection processes, different techniques can be differentiated depending on the required finish [1]. The injection process is common to all these techniques, but they differ in the superficial finish which is given to the injected part and the characteristics of the film on which the over injection is performed. Figure 1 shows different parts made by over injection with different materials.

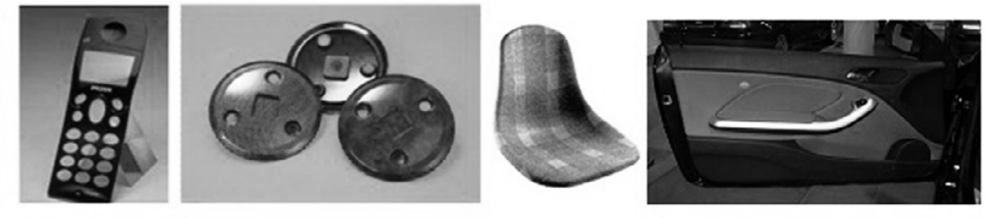

Figure 1: Items made by over injection process

One of the sectors where this transformation process is widely used is the automotive industry, where many interior parts of medium and high range cars are made by over textile injection [2-3].

The introduction of textile during the injection has an important influence over the process which produces significant differences from the conventional injection process. These differences entail appreciable changes in the mould design, in the injection parameters and in the defects and problems which may appear on these parts.

Simulation CAE tools like Moldflow® or Cadmold® are used for the design of plastic injection parts [4-6]. However, there are not any specific modules for the over injection process simulation in those CAE software. It is impossible to directly simulate the over injection as it is a very complex process due to the film or sheet introduced into the mould, which modifies all the variables of the injection of the plastic part. The introduction of a film or sheet affects the main parameters needed to carry out a simulation [7]. The most important of these parameters are:

<u>Thermal conductivity</u>

Simulation programs are designed to simulate heat transfer processes, shown in figure 2 between the metallic material of the mould and the injected plastic [8-9]. In order to calculate this heat transfer with Eq.(1), the program has thermal conductivity values of mould materials and different plastics in a database.

$$\lambda = t / R_{thermal} \qquad (1)$$

where λ is thermal conductivity, t is thickness and $R_{thermal}$ is thermal resistance.

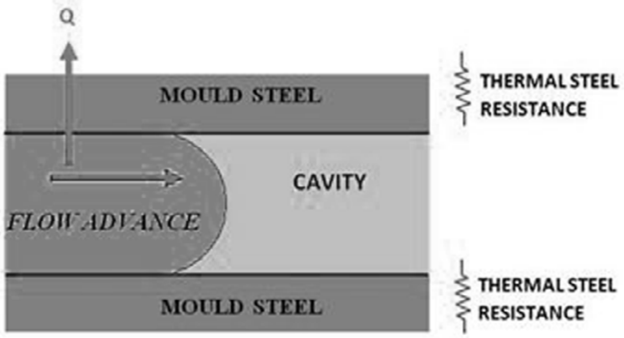

Figure 2: Heat transfer diagram of a plastic injection process

The film or sheets act as insulators during the injection process [10] as shown in figure 3, and simulation programs are not prepared to evaluate how thermal conductivity is affected with the introduction of these sheets between the mould cavity and the injected plastic.

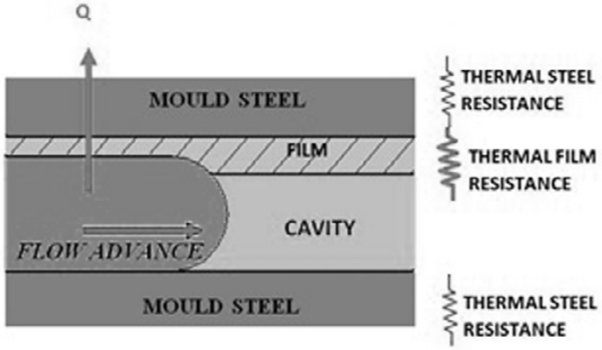

Figure 3: Heat transfer diagram of a plastic injection process with a film

Compression

Unlike steel, sheets and films are not rigid materials [11], and they are compressed while plastic flows inside the mould, so the flow area varies during the injection cycle depending on process conditions as shown in figure 4.

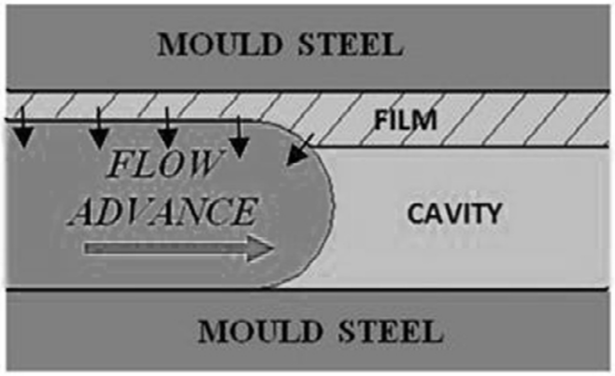

Figure 4: Flow area in plastic injection process with a film

Roughness

Texture and superficial finish of the film or sheet which contacts the plastic affects the flow advance during the injection [12], because the flow does not behave in the same way as over a polished surface like the steel of a mould. In over injection processes, only one side of the plastic part is contacting the film or sheet. The roughness difference between the mould steel and the film makes the flow asymmetric.

Films stress

During the injection of polymer material, the film is stressed due to the cavity geometry as described [13-14], see figure 5. Authors like Wong et al. have studied the influence of process temperature on film stretching [15].

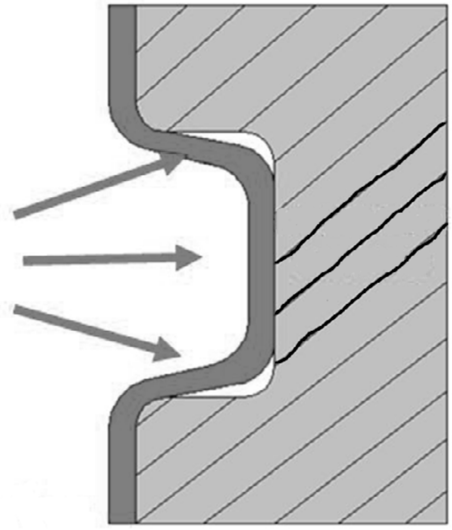

Figure 5: Stressed film during the injection process

All these factors seriously influence an over injection process, so they cannot be undervalued when performing a simulation of a process like that [16-17]. For example the effect on final part warpage is show in [18] and [19]. Regarding to rheological behaviour, Javierre et al. [20-21] have already developed a methodology to analyze rheological behaviour of flow under non-conventional conditions. Fernandez [22-23] developed a tool to characterize frozen layer fraction of the polymer flow taking into account thermal conductivity of the boundary surfaces of the flow. These two researches are used by Martinez et al. [24] to obtain some rheological characteristics of a single polymer-textile combination.

The first purpose of this paper is to develop a measurement method which can be used as an alternative to simulate textile overinjection moulding by conventional CAE tools. By means of the developed method it is possible to obtain an equivalent viscous model which takes into account the influence of the process conditions over the material viscosity and all the factors previously detailed which affect the fluidity of the material inside the mould during an over injection process. Then, this equivalent viscous model is combined with a numerical CAE simulation software Moldflow®, in order to simulate the over injection process taking into account the influence of the textile over the polymer fluidity. The second purpose of this work is analyze the influence of the type of textile on the over injection process by measuring maximum injection pressure of a pillar part over moulded with different types of textiles.

2. Experimental

2.1 Required equipment

The required equipment consists of a spiral mould, pressure sensors, a measurement chain, an injection machine, raw material and textiles.

2.1.1. Spiral mould

We have used a spiral mould [25-26], which is a test mould with a spiral cavity whose length is long enough that the majority of polymer materials cannot completely fill the cavity. By means of this mould, it is possible to characterize the behaviour of the melt polymer measuring pressure drop between two points of the cavity. This pressure drop has been measured while injecting under non-conventional conditions, such as over textile injection. Mould characteristics are a spiral cross section of 20 mm x 2 mm, and a total flow length of 1360 mm, a cold sprue of 70 mm long as feeding system, two cooling channels with spiral shape for a better adaptation to the part, and two pressure sensors.

Mould figure has each centimetre of the length measurement machined on it in order to be able to obtain the length of the injected part. This mould allows researchers to apply different process conditions in order to analyze different filling behaviours. See figure 6.

Figure 6: Spiral mould used for the tests.

The mould has a system to hold the textile film into one of the cavities, in the way that when mould is closed, plastic is injected over the textile. How to introduce the textile and the result of the injection are shown in figure 7.

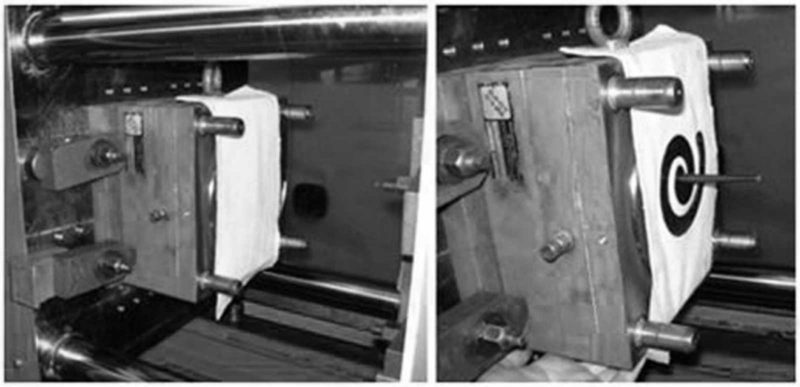

Figure 7: Introduction of the textile into the mould cavity

2.1.2. Pressure sensors

KISTLER 6157BBSP0 quartz sensors have been used as they are specially indicated for the measurement of injection processes. Its main features are a temperature range for the mould up to 300ºC, a temperature range for the melt material in front of the sensor up to 450ºC, a pressure range up to 2000 bar, a sensibility -4 pC/bar, and a natural frequency>100Hz.

2.1.3. Measurement chain

A measurement chain is necessary to register pressure values obtained by the sensors during the injection trials. These sensors are located inside the mould, and they are connected to measurement equipment by means of extensor wires. This measurement equipment is connected to a computer that will capture the registered data. All data measured by the pressure sensors are graphically and numerically stored by means of a DFPLUS software.

Sensors begin to register pressure values different from zero when melt plastic reaches them. Pressure increases while material flows inside the mould, and maximum values are obtained at the end of the process. When the melt material reaches the second sensor, a pressure drop value can be measured. This value is used for the rheological characterization of the process. Figure 8 shows the position of the sensors into the mould.

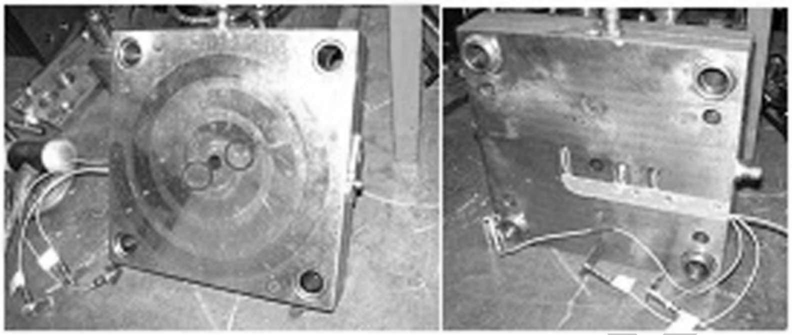

Figure 8: Location of the sensors into the mould

2.1.4. Injection machine

The injection machine which has been used to carry out the over injection tests is a Mateu&Sole of 55 t clamping force, 50 g/s plastification capacity, 1735 bar of maximum pressure, and a mould thickness of 120-300 mm. These dimensions are appropriate both in size and clamping force to inject the spiral mould to perform these tests, see figure 9.

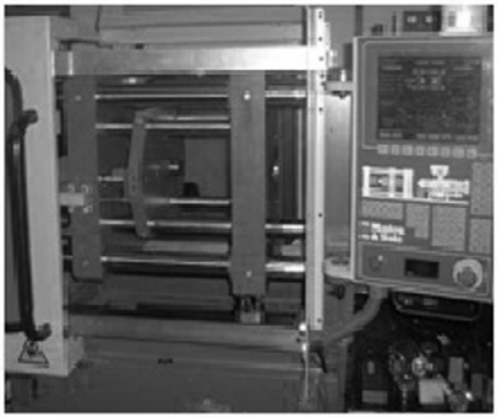

Figure 9: Injection machine used for the tests.

2.1.5. Raw material

Raw material used for these tests is polypropylene, *PP HC 31 STAMYLAN,* frequently used in textile injection parts. The thermoplastic properties of this material provided by the manufacturer are shown in Table 1:

RECOMMENDED PROCESS CONDITION	
Mould temperature	20 -60ºC
Material temperature	220 -270 ºC
Expulsion temperature	76 ºC
Maximum Shear stress	0,25 MPa
Maximum Shear rate	100000 1/s
THERMAL PROPERTIES	
Specific heat at 240 ºC	2690 J/kg·C
Thermal conductivity at 240 ºC	0,18 W/m·C

Table 1: Thermoplastic properties of PP HC 31 STAMYLAN

2.1.6. Textiles

Two different textile films are going to be used to fulfill the tests in order to compare their behaviours. They are named textile A and textile B. Textile A is a fabric used in pillar parts inside automobiles. This fabric is made out of three layers, as shown in figure10. The inner layer is called barrier film, it is white and it is the side contacting the injected plastic part. The intermediate layer is a 2 mm thick foamed one. The outer layer is the external one, the visible side of the part.

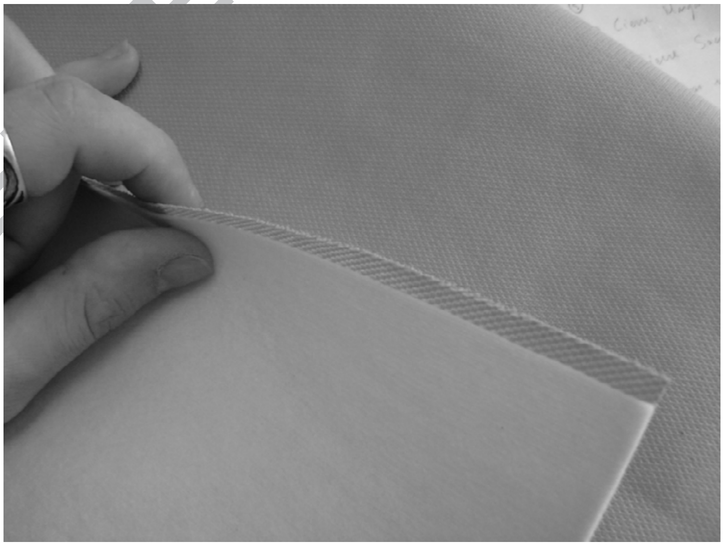

Figure 10: Both sides of textile A

Textile B is a fabric used for internal parts in automobiles, like door medallions. This fabric is also formed by three layers as shows figure 11. The inner layer is also the barrier film. The intermediate layer is a 5 mm thick foam, thicker than the intermediate layer of textile A. This causes a reduction of the plastic flow section during the injection. The outer layer is the visible side of the parts.

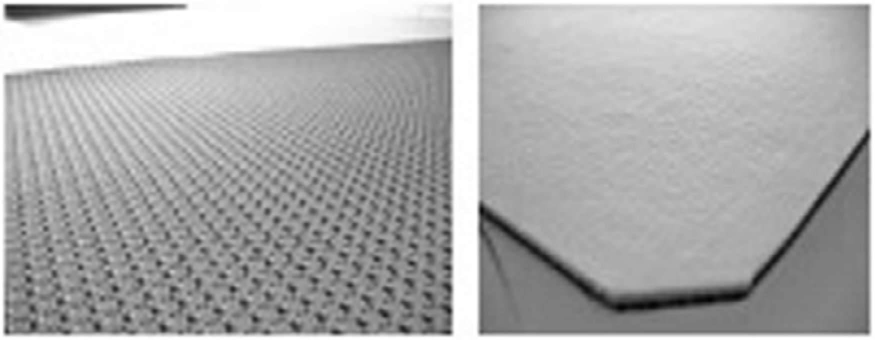

Figure 11: Both sides of textile B

2.1.7. CAE software

To analyze the influence of the type of textile on injection moulding process parameters, different simulations have been carried out. The CAE software used was MOLDFLOW© copyrighted by 2003 Moldflow Corporation. This software allows the introduction as input data of different constant values for the rheological model of different textile and thermoplastic materials and to obtain and compare simulation results. The simulated part was an automobile pillar whose general dimensions are 645.5mm x256mmx 2.7mm, shown in figure 12.

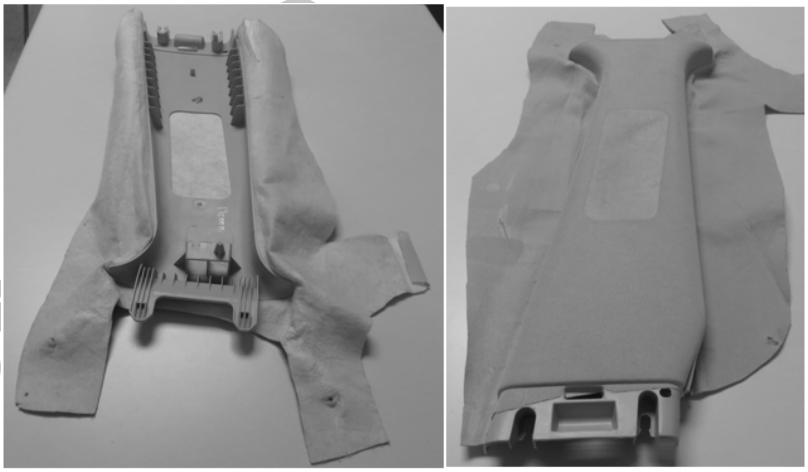

Figure12: Simulated automobile pillar part

2.2. Procedure

The goal of the measurement method is to get a viscous model from pressure registrations made in a spiral mould while injecting over the textile material which is being characterized. With this measurement method the behaviour of the thermoplastic material when it is injected over textile will be characterized and it can be compared with the behaviour of the thermoplastic material without textile. The rheological characterization method can be seen in detail in Clavería et al. [20]. This paper shows an application of this characterization method in non-conventional conditions that can be summarized up in six steps: 1 determination of injection tests conditions: temperature range, flow rate, and maximum pressure range; 2 injection of the spiral mould using pressure, temperature and flow rate ranges previously chosen; 3 analysis of the pressure data obtained by the sensors during the injection process using an EXCEL spreadsheet to work with them in a simpler way; 4 viscosity values calculation from pressure data; 5 application of VISDAT to obtain the model constants; 6 plotting of the viscosity curves from the rheological model constants for both, conventional and non-conventional conditions.

3. Methodology

3.1. Injection conditions

Material temperatures

The overinjection is analyzed using three different material temperatures, trying to cover a wide range of temperatures within the recommended ones by the material manufacturer. It must be take into account the maximum temperature allowed by the film which is going to be over injected. So, the over injection tests temperatures for the calculation of the viscous model are: 200ºC, 220ºC and 240ºC.

Injection speed

Depending on the machine injection rates, four different injection speeds are going to be programmed in order to be able to calculate four viscosity values corresponding to these four different injection rates. The exact injection speed value is not critical as the flow rate will be obtained at each essay with the time values obtained by the pressure sensors. The values are experimentally determined, as plastic must reach both pressure sensors in order to achieve proper measurements. This requirement must be met even when the injection conditions are unfavourable. The rates at which essays are made are percentages of maximum and minimum injection speed given by the technical characteristics of the injection machine. These percentages are 25, 50, 75 and 100%. For each type of textile, over injection is tested at three different temperatures, four injection rates for each temperature and for each combination, and five equal injections. Pressure results can be obtained from the experiments thanks to the different sensors, as well as the time intervals between sensors, as shows figure13.

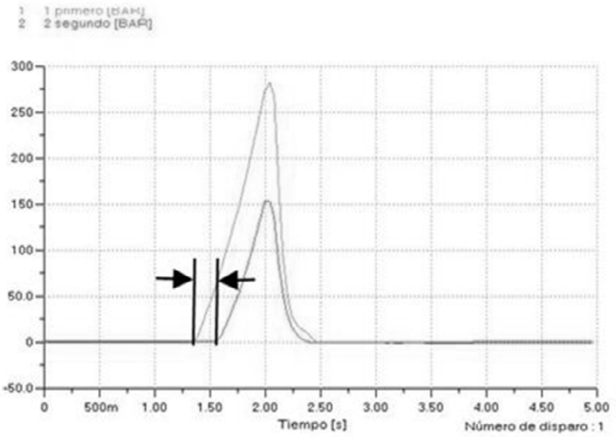

Figure 13: Material time intervals between sensors

3.2. Injection trials.

Injection trials under the previous conditions are made. From each combination of conditions, pressure values from five different shots are registered, making sure that the machine is working under stable conditions. This guarantees that the injected parts are being produced under the parameters introduced in the machine control panel.

3.3. Analysis of the registered data.

After finishing the injection trials at different process conditions, pressure data are analyzed. For each injected spiral (figure 14), pressure measurements from different sensor locations have been registered. Results are extracted in two different ways, as a text file storing all the numerical pressure values along time, and as a graphic where pressure values are shown versus test time. For viscosity calculations, pressure drop between sensors is calculated when the material reaches the second sensor.

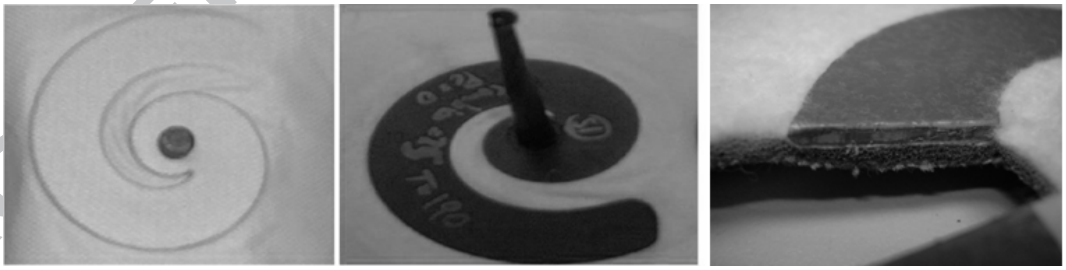

Figure 14: Injected over textile spiral

3.4. Viscosity calculation

Viscosity is a material parameter which depends on pressure, temperature and flow rate conditions. The methodology used for the viscosity calculation is based on the following equation, Eq. (2):

$$\eta = 4\Delta P a^3 b / 3QL \qquad (2)$$

Obtained from the combination of the following equations, Eq. (3), Eq. (4) and Eq. (5):

$$\eta = \tau / \gamma \qquad (3)$$

Where: η = viscosity
τ = shear stress
γ = shear rate

$$\gamma = 3Q / 4a^2 b \qquad (4)$$

$$\tau = \Delta P a / L \qquad (5)$$

Where: Q is the injection flow rate (m^3/s)
$a = 0{,}001m$ is the spiral cross section height

$b = 0{,}01m$ is the spiral cross section width

$L = 0{,}085m$ is the distance between the location of the two sensors where pressure drop is measured.

ΔP is pressure drop measured between two sensor locations (Pa).

The methodology used for obtaining the viscous model in non conventional situations is explained at Clavería et al. [20].

Shear rate and viscosity values are introduced in the VISDAT, and the six constants which define the viscous behaviour for each tested film are obtained by the second order equation of the viscous model, Eq. (6).

$$Ln(\eta) = A_0 + A_1 \cdot Ln(\gamma) + A_2 \cdot T + A_3 \cdot Ln(\gamma)^2 + A_4 \cdot T \cdot Ln(\gamma) + A_5 \cdot T^2 \qquad (6)$$

Where: η is viscosity (Pa·s).
A_0, A_1, A_2, A_3, A_4 and A_5 are material constants
γ is shear rate (s^{-1})
T is temperature (^oC).

These constants can be introduced in conventional injection simulation programs to perform realize all the calculations.

4. Results

4.1. Calculation of the viscous model of an overinjection process with the developed methodology.

Using the equations corresponding to pressure drop and times obtained with pressure sensors, viscosity values are calculated for each type of textile, temperature and injection rate tested, which are shown in Table 2 and Table 3. Viscosity was obtained as the average of the shots, not taking into account those of maximum and minimum viscosity value, and using three shots for the average.

Tª(ºC)	% v	ΔP(Pa)	S. RATE(s^{-1})	VISCOSITY(Pa·s)
200	25	8017900	900	105
	50	8705800	2250	46

	75	8731600	3000	35
	100	9085700	3750	29
220	25	7214600	900	94
	50	7758000	2250	42
	75	8331800	3000	32
	100	8484200	3750	26
240	25	6314600	900	84
	50	7171800	2250	38
	75	8185300	3000	29
	100	7785900	3750	24

Table 2 Viscosity values for textile A

T^a(ºC)	% v	ΔP(Pa)	S. RATE(s^{-1})	VISCOSITY (Pa·s)
200	25	8600000	900	112
	50	9300000	2250	49
	75	9800000	3000	38
	100	10300000	3750	32
220	25	8101800	900	106
	50	6745900	2250	45
	75	9000000	3000	35
	100	9600000	3750	30
240	25	7310000	900	96
	50	7999900	2250	42
	75	8394800	3000	33
	100	8600000	3750	28

Table 3 Viscosity values for textile B

The constants for the viscous model can be obtained from these values. Table 4 shows constant values for the second order viscous model of each tested film. It is important to understand that this is not a conventional viscous model as considered in [27-29]. Ponz [21] considers it a pseudo viscous model, as viscosity is affected by the introduction of the textile, and the viscosity values obtained are the equivalent viscosity values of a conventional viscous model.

MATERIAL	A_0	A_1	A_2	A_3	A_4	A_5
FILM TYPE A	11,769	-0,95	-3,39E-03	-3,44E-03	4,66E-04	-1,14E-05
FILM TYPE B	10,835	-0,955	5,09E-03	7,45E-03	-2,24E-04	-1,70E-05

Table 4 Constants values for each type of textile

These results can be compared between them and with the corresponding results of PP Stamylan PHC 31 without textile. Following the same characterization process in order to evaluate the influence in the mould filling of each textile, Table 5 shows the viscosity values for this material at different conditions, and Table 6 shows the constants for the second order viscous model.

Tª (ºC)	% v	ΔP (Pa)	S. RATE(s^{-1})	STRESS	VISCOSITY
200	25	6282150	900	73908	82
	50	7143413	2250	84040	37
	75	7396725	3000	87020	29
	100	7548713	3750	88808	24
220	25	5572875	900	65563	73
	50	6383475	2250	75100	33
	75	6788775	3000	79868	26
	100	6991425	3750	82252	22
240	25	5167575	900	60795	67
	50	5876850	2250	69139	30
	75	6028838	3000	70928	24
	100	6332813	3750	74504	20

Table 5 Viscosity values for PP Stamylan PHC 31

A_0	A_1	A_2	A_3	A_4	A_5
11,193	-0,814	-5,672E-03	-8,526E-03	4,064E-04	-4,627E-06

Table 6 Constants values for PP Stamylan PHC 31

Figure 15, figure 16 and figure 17 show the comparison of viscosity values for each film type and for the plastic without film for different shear rate values and for three different temperatures.

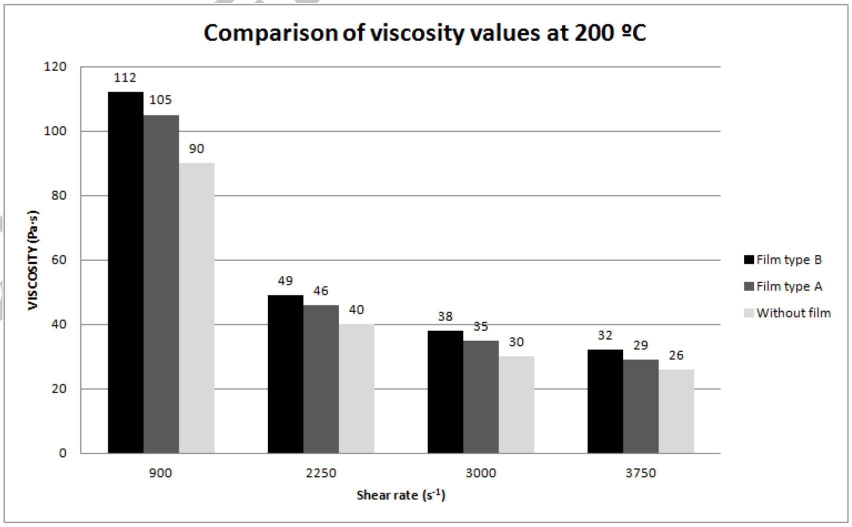

Figure 15: Comparison of viscosity values at 200 ºC.

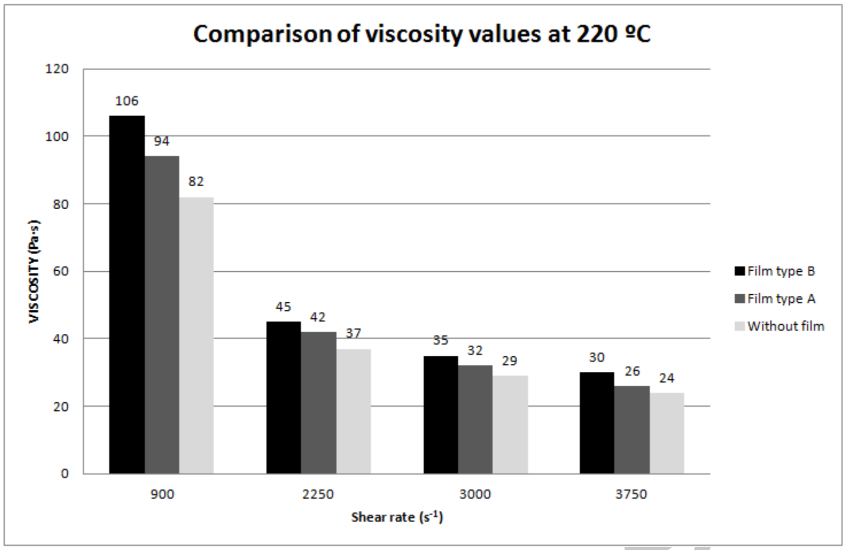

Figure 16: Comparison of viscosity values at 220 ºC.

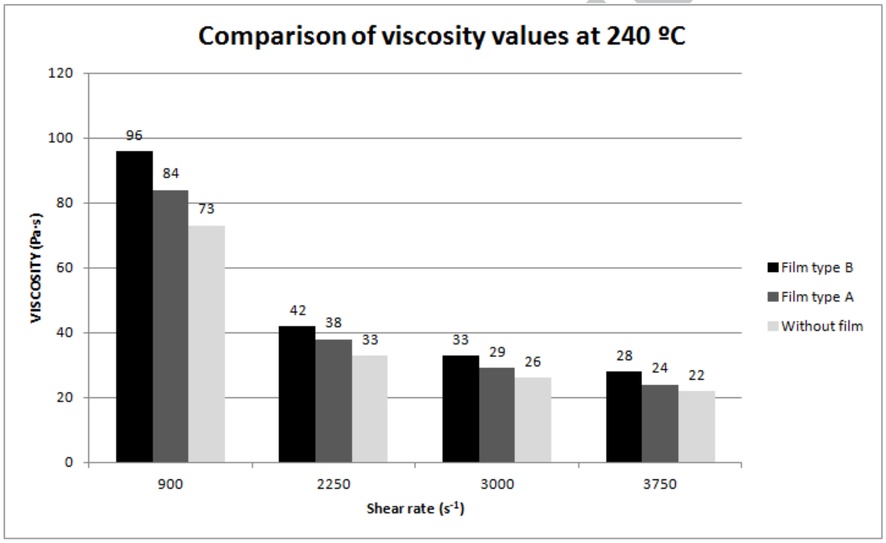

Figure 17: Comparison of viscosity values at 240 ºC.

Table 7 shows the percentage increase of the equivalent viscosity due to the introduction of the two different films at 200ºC, 220 ºC and 240 ºC.

		200ºC		
S. RATE(s^{-1})	900	2250	3000	3750
FILM TYPE A	**16.66**	**15%**	**16.66 %**	**11.53 %**
FILM TYPE B	**24.44**	**22.5 %**	**26.66 %**	**23.07 %**
		220ºC		
S. RATE(s^{-1})	900	2250	3000	3750
FILM TYPE A	**14.63**	**13.51 %**	**10.34 %**	**8.3 %**
FILM TYPE B	**29.27**	**21.62 %**	**20.69 %**	**25 %**
		240ºC		
S. RATE(s^{-1})	900	2250	3000	3750
FILM TYPE A	**15 %**	**15.15 %**	**11.54 %**	**9 %**
FILM TYPE B	**31.5 %**	**27.27 %**	**26.92 %**	**27.27 %**

Table 7 Percentage increase of equivalent viscosity

4.2. Calculation of textile injection pressure by using different textiles

Using the viscous models obtained by means of the spiral mould, the influence of the introduction of different textiles into the cavity on the overmoulding process can be analyzed, by comparing results obtained with the aid of MOLDFLOW® CAE tool. Table 8 shows the maximum injection pressure results obtained when applied to a standard automobile pillar part, shown in Fig. 12. It can be observed that injection pressure is 16%-22% higher when different films are introduced into the mould cavity. If textile overmoulding process simulations are carried out with conventional viscous models instead of with the obtained textile viscous models, results will not be reliable and the viability of the cavity design will be affected.

	Characterized material	FILM type A	FILM type B
Maximum injection pressure (MPa)	31	36	38

Table 8 Pressure values for a textile overinjected part with two different textiles

5. Conclusions

A new measurement method to characterize the textile overinjection molding has been presented in order to see the influence of different textile films on the plastic flow. This method uses a spiral mould monitorized with pressure sensors, and with it, a viscous model characterizing the behaviour of the plastic material during the textile injection process is calculated. The obtained viscous model can be used with conventional injection CAE tools to simulate textile injection processes.

Two different textiles used in the automotive industry have been characterized, and an automobile pillar injection have been simulated with the viscous model of textile-plastic material and with the two viscous models obtained with the two different textiles characterization.

Results make clear how the introduction of different films affects the material flow inside the mould. Viscosity values at different injection rates are 8.3-16.66% higher when using textile A, and 20.69-31.5% higher when using textile B. This behaviour is very similar at the three tested temperatures.

Also it can be perceived that depending on the film type introduced inside the mould, the equivalent viscosity of the injected material changes differently. It can be checked that the equivalent viscosity for textile B is 6 -17% higher than for textile due mainly to their different thickness. The increase in thickness of the introduced film reduces the flow section of the plastic injected material, increasing by this way the viscosity, if we compare it with the conventional injection of the same plastic material without textile.

When measured viscosity values are introduced into an injection CAE tool, injection pressure increases between a 16-22% regarding the type of textile, for the selected application.

References

[1] Berins, M.L., 1991. Plastics Engineering Handbook of the Society of the Plastics Industry, 5th ed., Van Nostrand Reinhold, New York.

[2] Staunber R., Vollrath L., 2007. Plastics in automotive engineering, Hanser Publishers, Munich.

[3] Maxwell, J., 1994. Plastics in the automotive industry. Woodhead Publishing Ltd.

[4] Lee, C.C., Castro, J.M., 1989. Model Simplification in Fundamentals of computer modeling for Polymer Processing, Ed. C.L. Tucker III Hanser Publishers, Munich, Vienna, New York.

[5] Tucker, C.L., 1989. Computer Modeling for Polymer Processing, Hanser Gardner Publications, Munich.

[6] Jiménez, E., Ruiz, I., Blanco, J., Pérez, M., Design and Simulation of Production of Injection Pieces in Automobile Industry, International Journal of Simulation: Systems, Science & Technology 10 (3) 2009 23-30.

[7] Shia-Chung Chen, Hai-Mei Li, Shih-Tsun Huang, 2010. Effect of decoration film on mold surface temperature during in-mold decoration injection molding process. International Communications in Heat and Mass Transfer. Pages 501-505.

[8] Youssef Farouq, Ce´cile Nicolazo, Alain Sarda, Re´mi Deterre, Temperature measurements in the depth and at the surface of injected thermoplastic parts, Measurement 38 (2005) 1–14.

[9] Shih-Jung Liu , Po-Chang Su, Kun-Yeh Lin, In-situ temperature measurements in the depths of injection molded parts, Measurement 42 (2009) 771–777.

[10] Shia-Chung Chen , Hai-Mei Li , Shih-Tsun Huang , Yi-Chao Wang, Effect of decoration film on mold surface temperature during in-mold decoration injection molding process, Int Commun Heat Mass 37 (2010) 501–505.

[11] C.O. Phillips, T.C. Claypole, D.T. Gethin, Mechanical properties of polymer films used in in-mould Decoration, J Mater Process Tech., 200(2008) 221–231.

[12] Peter, K., 1995. Flow Analisis of Injection Molds, Hanser Publishers, Munich.

[13] C.O. Phillips, D.C. Bould, T.C. Claypole, D.T. Gethin, Finite element modelling of low temperature forming of polymer films with application in in-mould decoration, Materials and Design 30 (2009) 537–550.

[14] Shia-Chung Chen a,b, Shih-Tsun Huang a, Ming-Chung Lin a,c, Rean-Der Chien. Study on the thermoforming of PC films used for in-mold decoration, Int Commun Heat Mass 35 (2008) 967–973.

[15] A.C-Y Wong K.Z. Liang, Thermal effects on the behavior of PET films used in the in-mould-decoration process involved in plastics injection moulding, J Mater Process Tech 63 (1997) 510-513.

[16] Hettinga, S., 1996. Controlled low-pressure injection moulding, Stevenson (Ed.), Innovation in Polymer Processing Molding, Hansher Publishers, Munich.

[17] Rothe, J., 1997. Special injection moulding methods, Kunstoffe 87, pages 1564-1581.

[18] R. Sánchez, J. Aisa, A. Martinez, D. Mercado, On the relationship between cooling setup and warpage in injection molding, Measurement 45 (2012) 1051–1056.

[19] Hui-Li Chen, Shia-Chung Chen, Won-Hsion Liao, Rean-Der Chien, Yu-Tseng Lin, Effects of insert film on asymmetric mold temperature and associated part warpage during in-mold decoration injection molding of PP parts, Int Commun Heat Mass 41 (2013) 34–40.

[20] Clavería, I., Javierre, C., Ponz, L., 2005. Method for generation of rheological model to characterize non-conventional injection molding by means of spiral mold. Journal of Materials Processing Technology. Volumes 162-163, pages 477-483.

[21] Ponz, L., Methodology for rheological characterization of thermoplastic materials under non conventional conditions for application on CAE tools. Case sample of a recycled PEHD, Thesis (PhD) (2009). University of Zaragoza (Spain).

[22] A. Fernández, CAD/CAE tools for thermoplastic injection molding design and quotation. Thesis (Ph.D) (1995) University of Zaragoza (Spain).

[23] Javierre, C., Clavería, I., Fernández, A., Aínsa, I., New tools and methodologies for training in thermoplastic injection molding process, EISTA 2011. The 9th International Conference On Education And Information Systems, Technologies And Applications, (2011) Orlando (US).

[24] A. Martinez, J. Castany, D. Mercado, Characterization of viscous response of a polymer during fabric IMD injection process by means a spiral mold, Measurement 44 (2011) 1806–1818.

[25] Amano, O., Ainoya, K., 2000. Pressure dependent viscosity of polymer melts, Antec'00 Conference Proceedings, p. 89.
[26] Barnes, H.A., Hutton, J.F., Walters, K., 1989. An introduction to rheology. Elsevier Science Publishers B.V., Amsterdam.
[27] Haghtalab, A., Hemmati, M., Alaie, J., 2000. Rheological study of polyethylene/polypropylene lends, Iranian Journal of Polymer Science Technology, 13(4), pages 211-216.
[28] Pillo, A., Dealy, J.M., Patterson, W.I., 1997. Upgrading recycled HDPE by rheometer controlled cosslinking, International Polymer Processing, 1, pages 4-10.
[29] Rosenbaum, E.E., Hatzikiriatos, S.G., 1996. Effect of viscous heating in capillary rheometry, Antec'94 Conference Proceedings I, pages 1080-1084.

FIGURE CAPTIONS

Figure 1: Items made by over injection process
Figure 2: Heat transfer diagram of a plastic injection process
Figure 3: Heat transfer diagram of a plastic injection process with a film
Figure 4: Flow area in plastic injection process with a film
Figure 5: Stressed film during the injection process
Figure 6: Spiral mould used for the tests
Figure 7: Introduction of the textile into the mould cavit
Figure 8: Location of the sensors into the mould
Figure 9: Injection machine used for the tests
Figure 10: Both sides of textile A
Figure 11: Both sides of textile B
Figure 12: Simulated automobile pillar part
Figure 13: Material time intervals between sensors
Figure 14: Comparison of viscosity values at 220 ºC
Figure 15: Comparison of viscosity values at 240 ºC
Figure 16: Pillar part

TABLES

Table 1: Thermoplastic properties of PP HC 31 STAMYLAN
Table 2: Viscosity values for textile A
Table 3: Viscosity values for textile B
Table 4: Constants values for each type of textile
Table 5: Viscosity values for PP Stamylan PHC 31
Table 6: Constants values for PP Stamylan PHC 31
Table 7: Percentage increase of equivalent viscosity
Table 8: Pressure values for a textile overinjected part with two different textiles

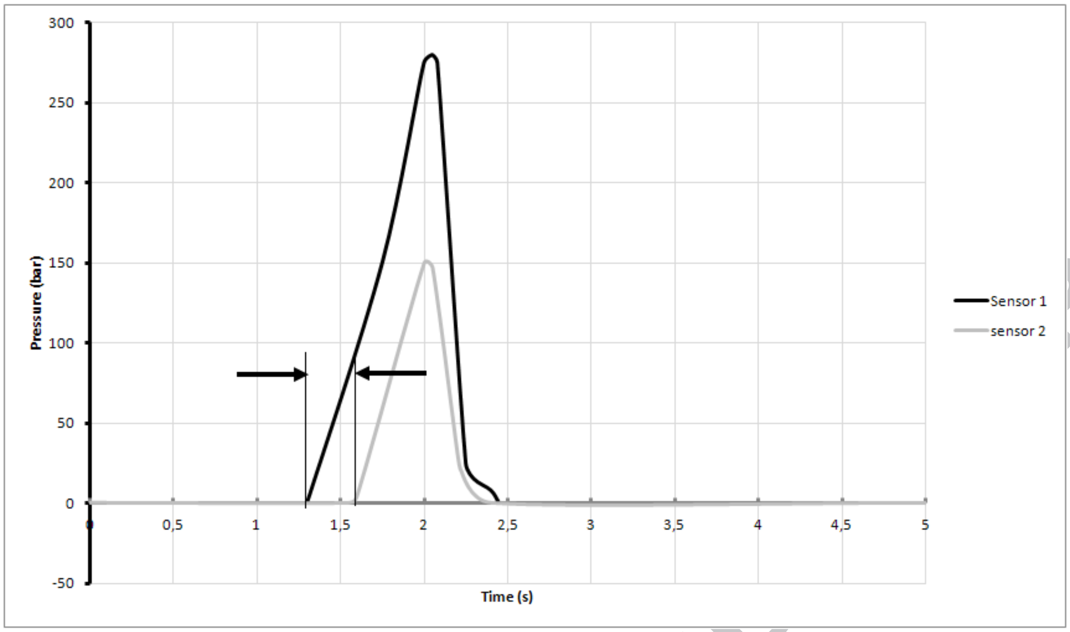
300
250
200
150
100
50
0
-50
Pressure (bar)
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
Time (s)
Sensor 1
sensor 2

Fig.13

HIGHLIGHTS

- A new measurement method to characterize the textile overmolding flow is developed
- Flow characterization is used in CAE tools to predict textile injection process parameters
- Viscosity values increases up to 30% when textile is introduced into the mould.
- Appreciable differences are observed when different textiles are used, up to 17%.
- Injection pressure is increased up to 22% when textile is introduced into the mould.