NUMERICAL SIMULATION AND EXPERIMENTAL VALIDATION OF THE INJECTION PROCESS FOR PLASTIC PARTS

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REZUMAT: Lucrarea are ca scop realizarea unui model numeric al procesului de injecţie şi validarea lui prin experimente de injecţie pe baza cărora să poata fi facută o analiză a umplerii pieselor înainte de a demara testele fizice. Prin această metodă se poate ajunge la reducerea timpilor şi costurilor de testare pentru fazele de optimizare a programelor de injecţie.

Cuvinte cheie: curgere în matriţă, turnare.

ABSTRACT. This paper has as objective realization of a computational modeling of injection process and validation of it by injection experiments in order to be able to perform an analysis of part fill in before physical tests. By using this method time and cost of test phases can be reduced in order to optimize the injection programs.

Keywords: Mold Flow, Molding.

1. INTRODUCTION

Day by day car manufacturers are looking more often to cost reduction solution. Time for performing the tests before launching a new project is one of the key. Main role of this paper is to present a computational modeling for injection process in order to be validated by injection experiments. In this way, time and costs for setting process parameters are reduced.

2. METHODOLOGY

The 3D model of the bumper was used to extract the geometrical features required by the numerical model for the molding analysis.

Currently Mold flow can work with three different models: solid, fusion - a surface model that is generated on the outer surfaces of the part and mid surface - generated on the middle surface. For large parts the recommended method is the mid surface model. As a consequence some work is required in order to define the middle surface from the skin.

For this particular model this procedure is relatively simple because there are not too many add on features such as reinforcing wall and stiffeners.

The extracted mid surface is used as a support for the numerical model. Mold Flow requires a triangular shaped finite element this being as a consequence the selected meshing method for the part.

Thickness has to be assigned to each element of the model. A thickness analysis is performed on the 3D model of the part. If large variations of the thickness are recorded then the elements should be grouped in parts sharing the same thickness. Otherwise a constant thickness can be assigned to the entire model.

Once finished the numerical model is imported into the Mold Flow environment for further operation. Injection points, material and process parameters are defined. The simulation phase is set to Fill + Pack + Warp that can provide the maximum of available information in the absence of a specified cooling system.

3. RESULTS AND DISCUSSIONS

In our case the simulation has been done for front bumper H79 (Duster). The results and thickness analysis are presented in table below.

Filling phase:

Status: V = Velocity control; P = Pressure control; V/P= Velocity/pressure switch-over

In the second part of the paper, the validation of the numerical simulation has been done by using real injection for front bumper H79. 2700 tones machine with external sequential unit has been used. The sequential unit has been set as continuously opened for all 10 injection nozzles. Fig 2 illustrates the injection time for each nozzle set from 0s to 99s in order to keep them opened all along the cylinder stroke.

Table 1. **Injection simulation results**

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
0,14	4,71	2,73	3,97	1300,02	V
0,28	9,39	3,95	11,3	1320,41	V
0,42	14,13	4,91	20,41	1329,78	V
0,56	18,91	5,76	31,01	1334,78	V
0,7	23,68	6,53	42,79	1335,24	V
0,84	28,31	7,24	55,77	1334,97	V
0,98	33,05	7,97	71,74	1336,79	V
1,12	37,69	8,72	92,58	1337,62	V
1,26	42,41	9,53	118,59	1339,65	V
1,4	46,99	10,3	145,89	1340,79	V
1,54	51,67	11,13	178,29	1342,07	V
1,68	56,3	11,99	215,47	1343,97	V
1,82	60,87	12,82	253,81	1344,99	V
1,96	65,51	13,67	295,94	1346,38	V
2,1	70,03	14,51	342,06	1347,35	V
2,24	74,68	15,49	405,87	1346,18	V
2,38	79,12	16,9	557,68	1350,41	V
2,52	83,64	18,1	632,22	1349,88	V
2,66	88,08	19,71	734,67	1351,67	V
2,8	92,31	23,85	1037,73	1354,19	V
2,94	96,46	28,9	1446,99	1354,21	V
2,99	97,92	31,39	1615,58	1335,13	V/P
3	98,15	25,11	1534,5	269,67	P
3,08	98,99	25,11	1381,21	436,31	P
3,22	99,71	25,11	1422,29	215,63	P
3,36	100	25,11	1449,7	146,4	P
3,36	100	25,11	1450,6	144,67	Filled

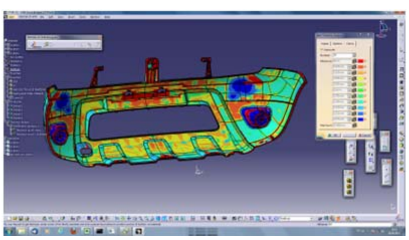

Fig 1. Thickness analysis.

Fig 2 10. injection nozzles activated.

Standard material and injection temperatures have been used (temperature curve around 240°C).

Fig 3. Full injection for each nozzle.

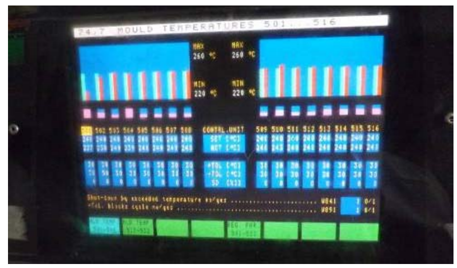

Fig 4. Tool temperature control.

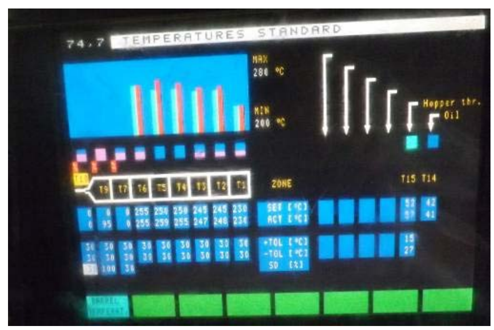

Fig 5. Tool temperature control..

The test has been started by finding the commutation point from dynamic injection to post pressure injection. As in numerical simulation, the commutation point has been found when reaching the 98%-99% of full part volume. The injection has been done without post pressure; the entire fill of the part has been done through dynamic injection.

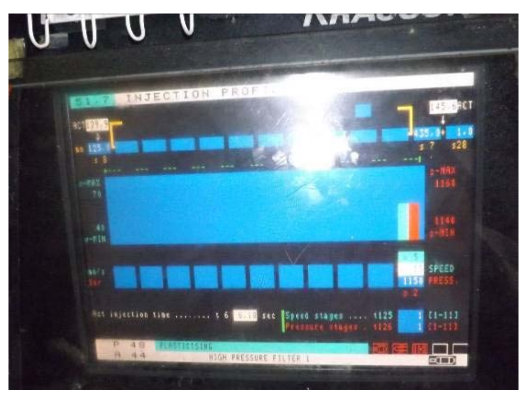

Fig. 6. Commutation point at 125 mm.

Fig 7. Part filled at 99% at commutation point.

Once the commutation point found at 125 mm, the injection stroke has been calculated as difference between the initial position (435 mm) of the screw and commutation point on the injection screw. The total injection stroke calculated is 310 mm.

There injection tests have been performed at the same % of screw stroke as in simulation. For each of these positions the comparation between numerical simulation and injection test has been done.

Test 1 – 37% of screw stroke from 435mm to 320 mm.

Fig. 8. Part injected at 37.69% of cylinder stroke.

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
1,12	37,69	8,72	92,58	1337,62	V

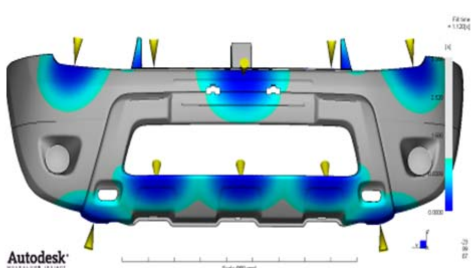

Fig. 9. Injection simulation at 37.69% of cylinder stroke.

All 10 injection nozzles has been opened the the part has similar volume as indicated in the simulation.

Test 2 – 70.03% of screw stroke from 435 mm to 218 mm.

Fig. 10. Status of part volume field in at 70.03%.

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
2,1	70,03	14,51	342,06	1347,35	V

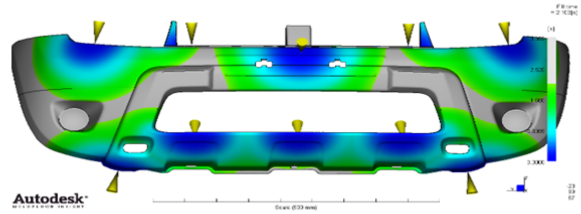

Fig. 11. Injection simulation at 70.03% of cylinder stroke.

The difference between the numerical simulation and injection test are visible only for upper side of the bumper but for the volume of such part the differences obtained are not considerable and the result can confirm the quality of the numerical simulation.

Test 3 – 96.46% of screw stroke from 435 mm to 136mm.

Fig. 12. Status of part volume field in at 96.46.

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
2,94	96,46	28,9	1446,99	1354,21	V

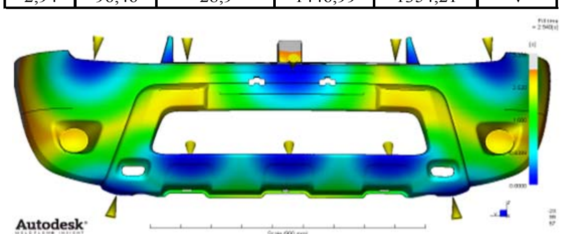

Fig. 13. Injection simulation at 96.46% of cylinder stroke.

As in simulation, at this stroke the part has reached 96% of each volume. At this value the dynamic injection should be stopped and the commutation to post pressure to be done, remaining 4% of volume being filled during this step.

4. CONCLUSIONS

The injection test has confirmed the conformity of the numerical simulation. By using numerical simulation further steps can be done such as the sequential opening of the nozzles during dynamic and post pressure phase. In any case for good simulation results the following aspects should be considered: central nozzle diameter, each tool nozzle diameter, temperature used for cylinder and tool and also the opening speed of the nozzles.

For plastic injection industry this method can be massively used in tool development for adjusting the nozzle position but also for setting the injection programs in test phases of a project. Setting of the injection program by numerical simulation can reduce the time and cost for physical tests and also can improve the quality of the product being able to see specific defects as welding lines, flow interference, air bubbles etc from earlier phases.

REFERENCES

[1] Ames NM., Srivastava V, Chester SA, Anand L. *A thermo-mechanically coupled theory for large defromations of amorphous polymers. Part II: Applications. International* Journal of Plasticity 2009, 25:1474-1494.

[2] Arriaga A, Lazkano J. M, Pagaldai R, Zaldua AM, Hernandez R, Atxurra R, Chrysostomou A. *Finite element analysis of quasi static characterisation test in thermoplastic materials: Experimental and numerical analysis results correlation with ANSYS.* Polymer Testing 2007; 26:284-305.

[3] Bartl F, Klaus H, Dallner R, Huber O, *Material behaviour of a cellular composite undergoing large deformation.* International Journal of Impact Engineering 2009; 36:667-679.