CFD ANALYSIS OF WINDSHIELD HEATER SYSTEM

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Abstract：Understanding the heat transfer interaction between inflow fluids and windshield surface is of ramount practical significance. In this paper, the heat transfer process is investigated utilizing a three-dimensional finite element method. Numerical analyses using Ansa and Thesues predict a detailed description of heat transfer. The answer shows the simulation method is feasible and convenient

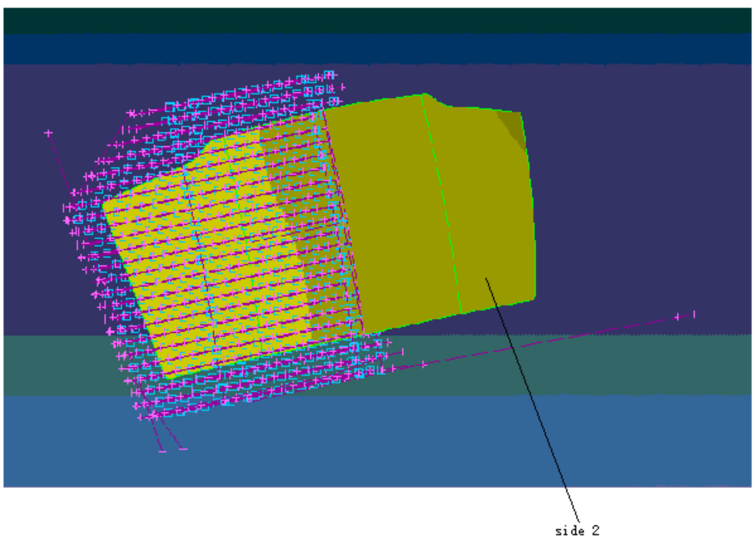
1 Introduction

Windshield is an important accessory to a car. With the progress in large curvature, hyperboloid, large spherical flat of windshield, trial and error method has been unable to meet the needs of development for new product. Therefore, the further research [1,2] of windshield hot-bend and tempering forming process, which combined with finite element numerical simulation technology, established a comprehensive numerical model, has the important theoretical significance and practical value. This paper deals with the numerical simulation analysis of windshield forming, and puts forward a usefull method for windshield design. Based on the 3D transient heat conduction theory, the mathematical models of windshield simulation are set up.With the instance of the windshield, the numerical simulation analysis of the transient temperature field has completed with finite element analysis software—THESUES and ANSA. In differente time, the distributions of the temperature of the windshield are gotten. The simulation result can be concluded that the simulation answer is acceptable and reliable.Finally, the paper summarizes windshield surface design ideas, which provides a reference for the processing technology of the windshield.

2 Question describe:

Figure 1 shows the geometry model of the winshield, the air flows from the winshield outside to winshield surfaces , the blue lines means the blowing grid.

The inlet air pressure near side 1 surface is 20Kpa, air temprature is 293K. The inlet air pressure near side 2 surface is 17Kpa, air temprature is 293K. Initial time, the windshield temperature is 923K. Blowing time is 15 second.



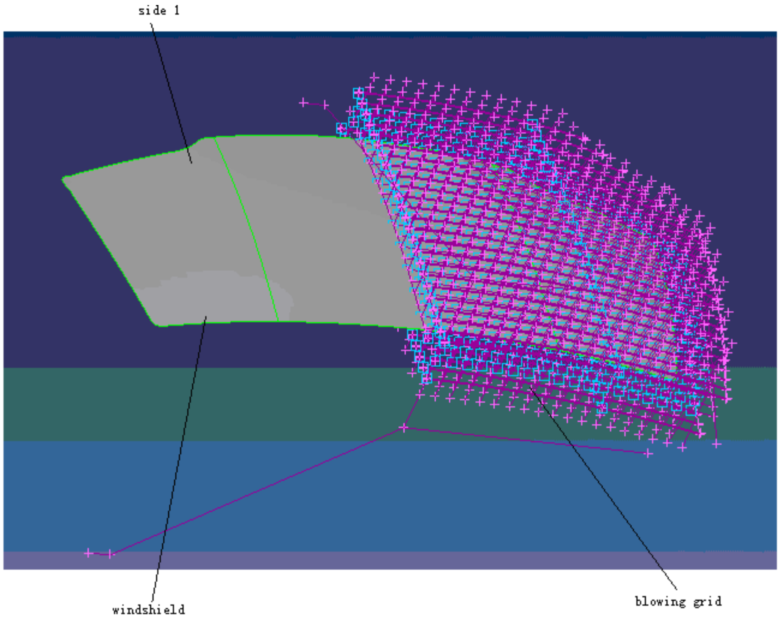


Fig. 1 The geometry model

3 Numerical method:

3.1 Theory about the windshield heat transfer analys[3]

For each material point in a solid regine, according the law of conservation of energy, the time rate of change of the total enegy is equal to the change of heat content per unit time.

$$\rho c\frac{\partial T}{\partial t}=-\nabla q+Q \qquad (1)$$

If working forces are not considered. Here, ρ denotes the density[kg/m^3], T the temperature[$^\circ C$], c the specific heat[$J/(kgK)$], q the conductive heat flux vector [W/m^2], and Q the internal heat generation[W/m^3]. Fourier's heat conduction law states:

$$q=-k\cdot\nabla T \qquad (2)$$

In terms of the conductivity tensor K. for a cartesian coordinate system $x=x_i e_i$ we get the following differential equation for the unknown temperature distribution in a solid region Ω:

$$\rho c\frac{\partial T}{\partial t}=\frac{\partial}{\partial x_i}(k_{ij}\frac{\partial T}{\partial x_j})+Q \qquad (3)$$

k_{ij} are components of the symmetric conductivity tensor. The indices i,j=1,2,3 represent the three coordinates. On the boundary region, for the windshield heat system, neglect the radiation from windshield, the energy conservation law leads to:

$$-(k_{ij}\frac{\partial T}{\partial x_j})n_i=q_{bc}=-q_{conv} \qquad (4)$$

The boundary heat fluxes $q_{bc}[W/m^2]$ consists of the convective q_{conv}. These heat fluxes are function of a position $s=(s_1,s_2,s_3)$ on the boundary and the time t. See figure 2.

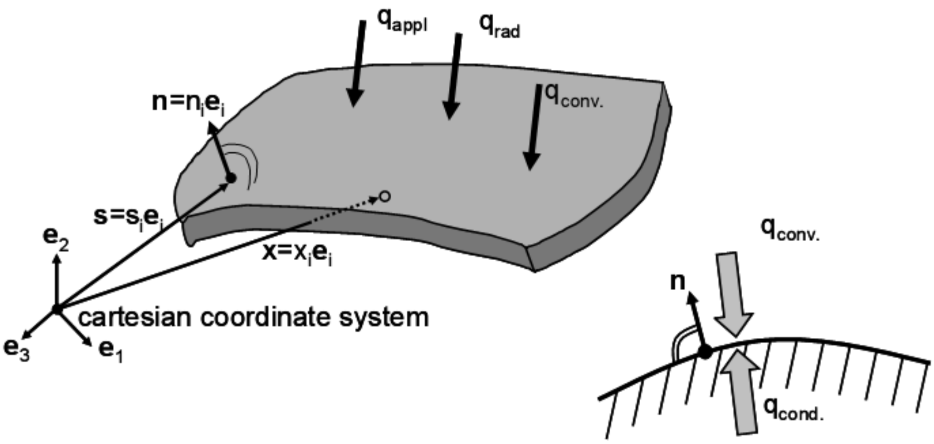


Fig.2 Solid structure with boundary conditions

3.2 Finite Element Approach

A so called weak form of (2) and (3) over a finite element is obtained by multipling (2) with a weight function $w(x)$ .The integral representation of the energy conservation law is follow:

$$\int_{\Omega^e} w[(\rho c \frac{\partial T}{\partial t} - Q) + k_{ij}\frac{\partial w}{\partial x_i}\frac{\partial T}{\partial x_j}]dx - \oint_{\Gamma^e} w(\sum q_{bc})ds = 0 \quad (5)$$

By the interpolation, the so-called weak-form of the finite element model is obtained:

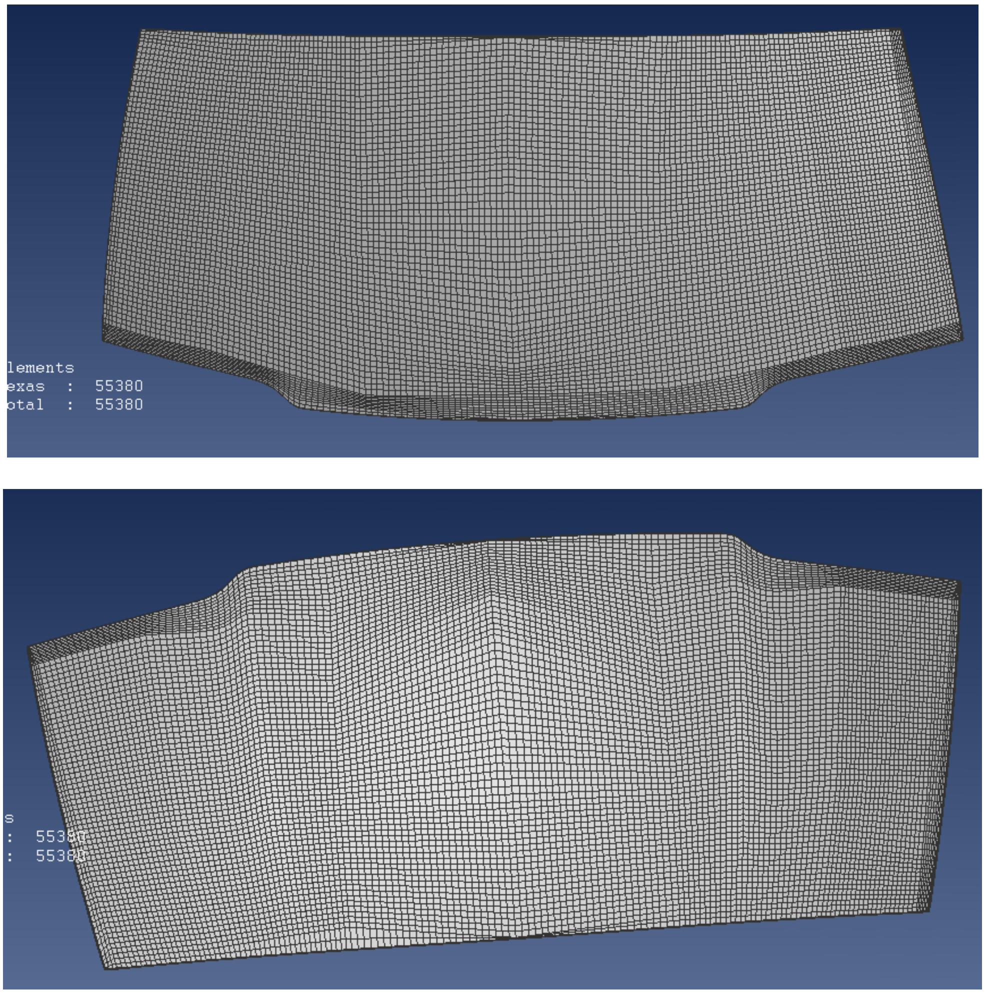
$$\sum (M_{ij}^e T_j^e + K_{ij}^e T_j^e) - Q_i^e - q_i^e = 0 \quad (6)$$

$$T_j^e = \frac{\partial T_j^e}{\partial t} \quad (7)$$

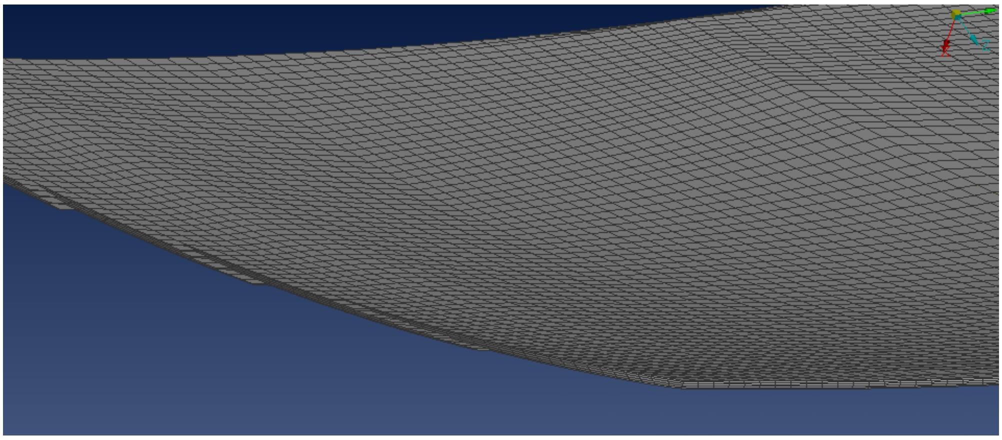
The details of (6) shows in reference[2].

3.3 Mesh generation

The hexa meshing is generated by ANSA, see figure3.



Surface grid



Inner grid

Fig 3 mesh

3.4 Analys method

The boundary condition:

$P_{side1} = 20KPa$,

$T_{side1} = 20^\circ C$,

$P_{side2} = 17KPa$,

$T_{side2} = 20^\circ C$.

Initial contition:

$t = 0s$,

$T_{windshield} = 600^\circ C$,

Material:

glass

Solver method:

Unsteady flow,

$t = 0,1,2,...,15s$

The convection coefficient between the air and the windshield is shown in fig4:

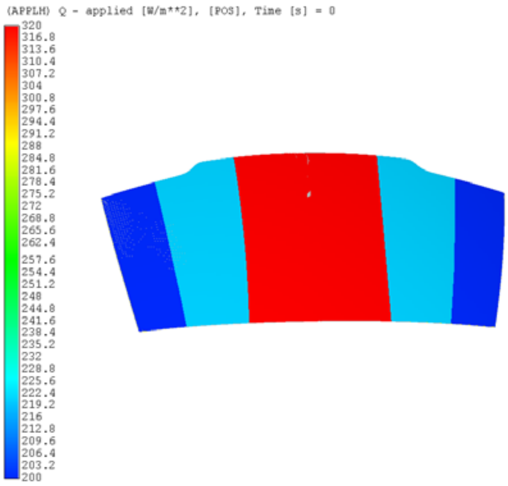


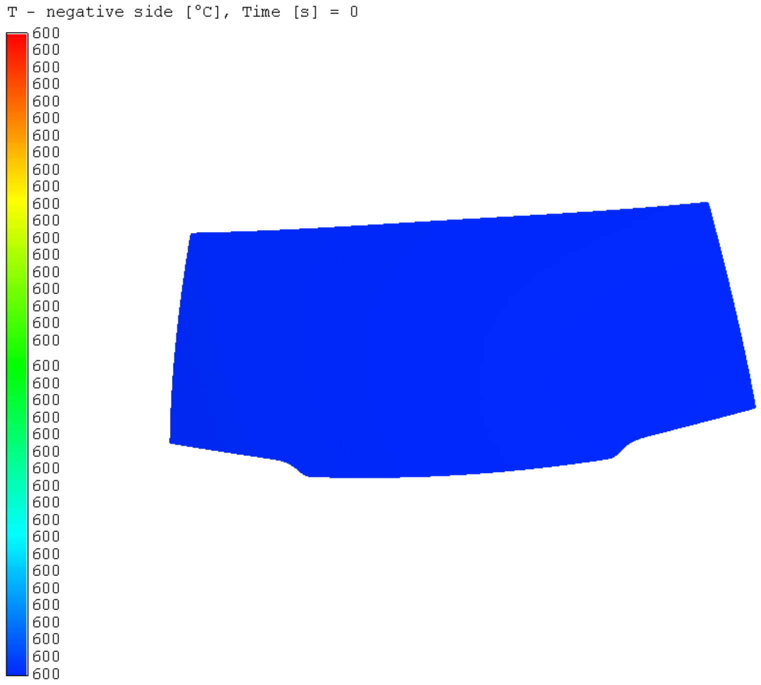
Fig4 surface convection coefficient

3.5 Result

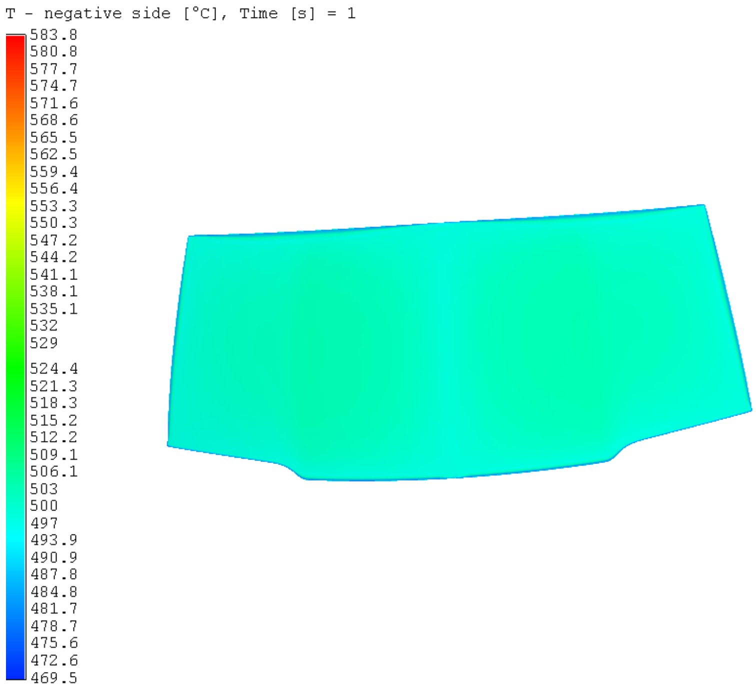
Figure 5 shows the windshield surface temperature distribution in differente time, when t=0s, the suface temperature is $600^\circ C$; when t=15s, the max temperature become $130^\circ C$, the min temperature become $49^\circ C$. These means that the windshield's temperature has fallen by 500 $^\circ C$ (at least) in 15 seconds.

The same conclusion can be tested in Figure6, these also show the process of heat transfer inside the windshield.

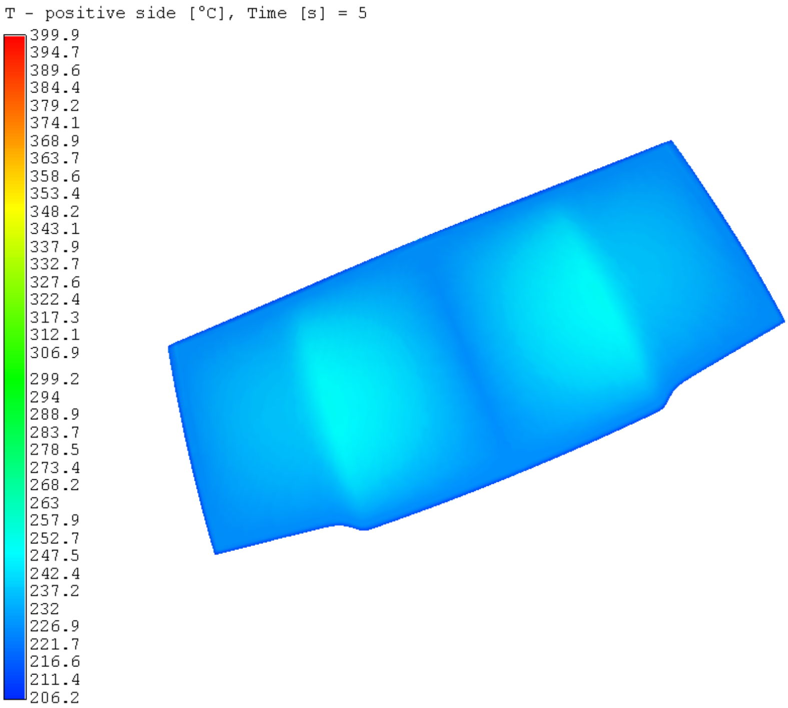
Figure 7 is the average temperature distribution in differente time, we can see that the average temperature has fallen by 525 $^{\circ}C$ in 15 seconds.



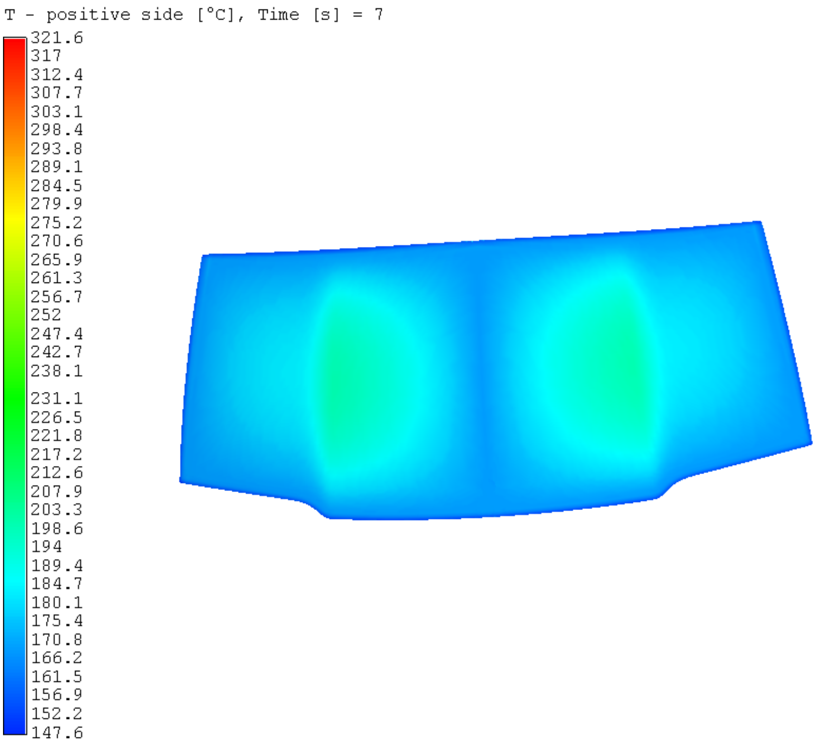
T=0s



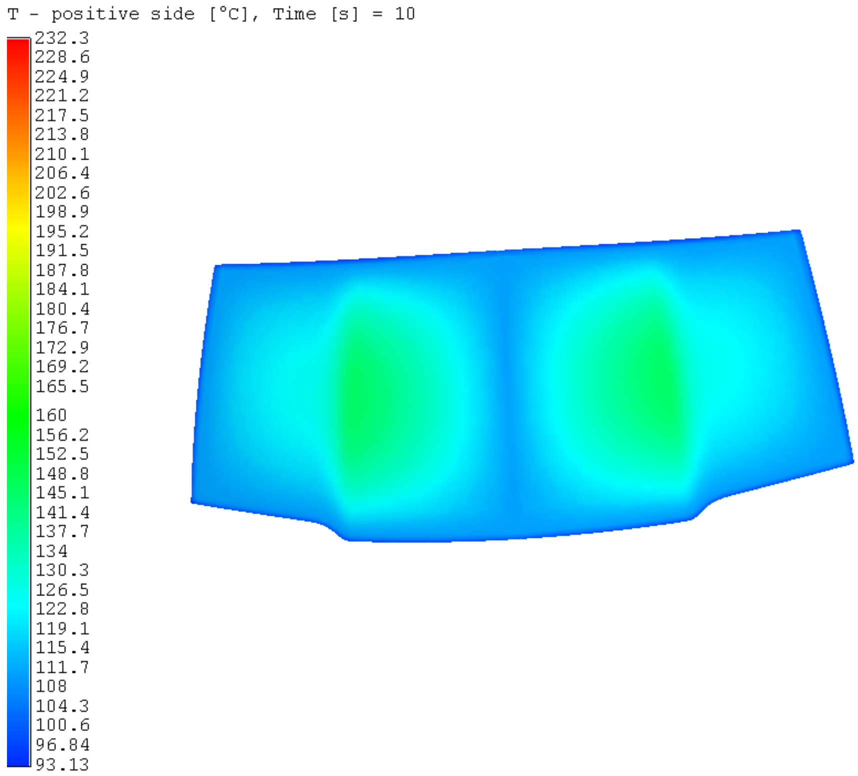
T=1s


T - positive side [°C], Time [s] = 5
399.9
394.7
389.6
384.4
379.2
374.1
368.9
363.7
358.6
353.4
348.2
343.1
337.9
332.7
327.6
322.4
317.3
312.1
306.9
299.2
294
288.9
283.7
278.5
273.4
268.2
263
257.9
252.7
247.5
242.4
237.2
232
226.9
221.7
216.6
211.4
206.2

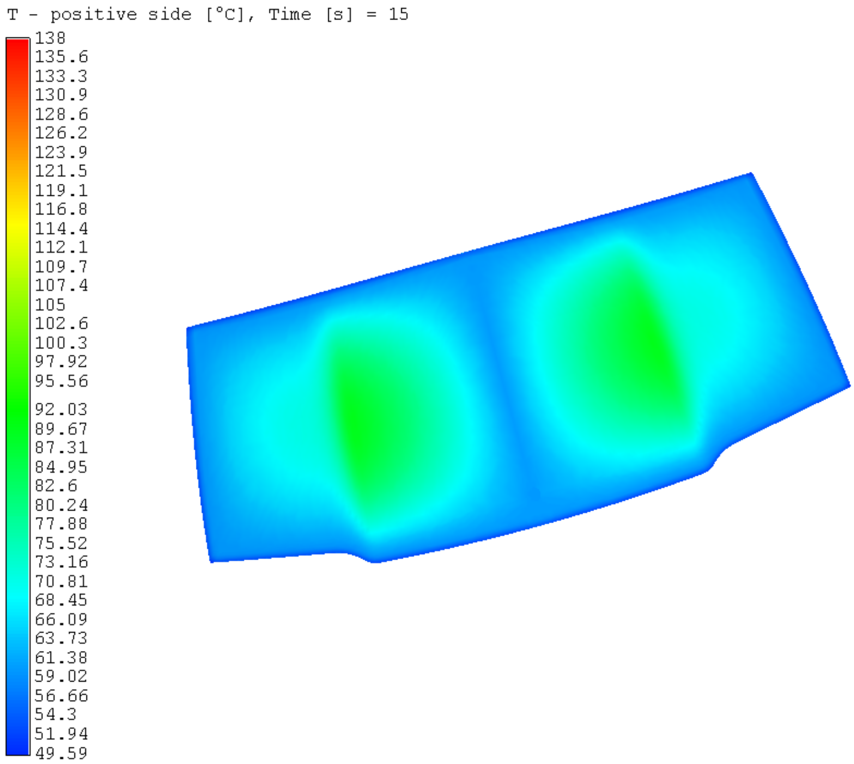
T=5s


T - positive side [°C], Time [s] = 7
321.6
317
312.4
307.7
303.1
298.4
293.8
289.1
284.5
279.9
275.2
270.6
265.9
261.3
256.7
252
247.4
242.7
238.1
231.1
226.5
221.8
217.2
212.6
207.9
203.3
198.6
194
189.4
184.7
180.1
175.4
170.8
166.2
161.5
156.9
152.2
147.6

T=7s

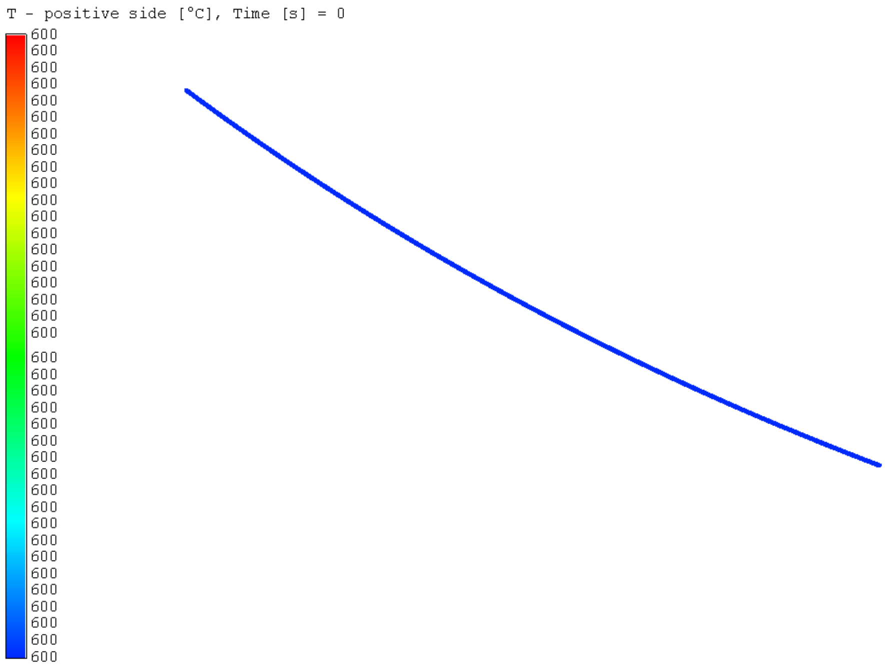


T=10s



T=15s

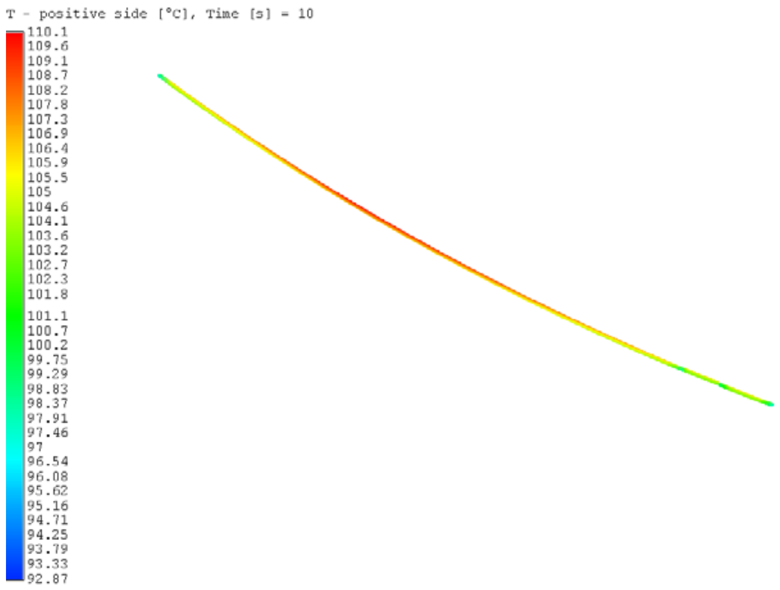
Fig.5 temperature distribution on surface


T - positive side [°C], Time [s] = 0
600

T=0s


T - positive side [°C], Time [s] = 5
232.1
231.4
230.8
230.1
229.4
228.8
228.1
227.4
226.7
226.1
225.4
224.7
224.1
223.4
222.7
222
221.4
220.7
220
219
218.4
217.7
217
216.3
215.7
215
214.3
213.7
213
212.3
211.6
211
210.3
209.6
209
208.3
207.6
206.9

T=5s



T=10s

T=15

Fig.6 temperature distribution inside the windshield

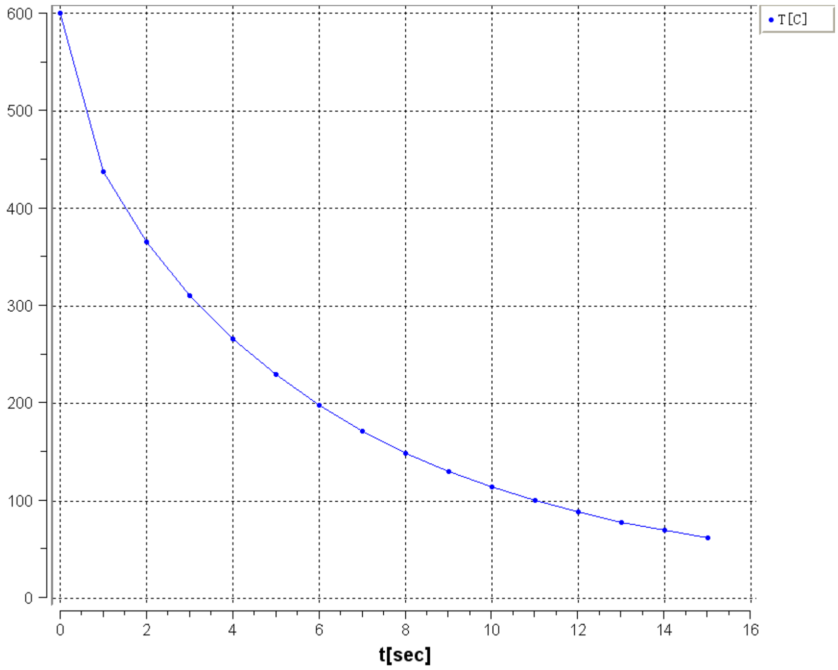


Fig.7 average temperature distribution

4 Conclusion

The analys model of unsteady temperature field about the windshield is established by Ansa and Thesues, the results shows the windshield temperature distribution with differente time. the temperature fall rapidly in 15 seconds, these are good correspond to reality. The simulative way will make the processing technology of the windshield more feasible and convenient.

Reference

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[2] Nasr, K.J. and AbdulNour. B.S. (2000) 'Defrosting of Automotive Windshields: Progress and Challenges', Int. J. of Vehicle Design. Vol. 23. Nos. 3/4, pp. 360-375.

[3] AbdulNour, R. S., Willenborg, K., Foss, J. F., McGrath, J. J., and AbdulNour, B. S., 1997, "Measurements of the Convective Heat Transfer Coefficient for a Two-Dimensional Wall Jet: Uniform Temperature and Uniform Heat Flux Boundary Conditions", Proceedings of ASME Heat Transfer Division, M.E. Ulucakli et al., Ed., HTD-Vol. 3, pp. 109-116.

[4] Thesues 3.1 Theory Manual.