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Thermal Transient and Thermal Stress on Radiated Heat Float Glass

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Abstract - To conduct an experiment of thermal radiation. The researchers conducted a simulation to study the behavior of the damage float glass using Mecway 10 FEA software. The ambient time and temperature on the first float glass sheet sustaining thermal transient and thermal stress are the most important parameters to find out the part of float glass. Analyzing the results of all simulations of radiant heat and convection in transient thermal simulations on the surface of float glass to be crack and knowing the estimated time until cracked float glass with thermal stress analysis. Giving heat radiation to the exposed glass surface, to be assumed by heat exposure from 0 to 20 minutes which is 32º to 600ºC with 19 mm glass thickness using Mecway 10 FEA software. Then did a comparison of the radiation heat value convection flow rate and so that the glass experiences a thermal crack. In this process, the results of the comparison will also be reviewed and discussed at the limit of the amount of heat radiation so that the cracked glass or thermal crack. The difference in temperature and stress will increase with adding radiation heat on the glass. Critical time and temperature differences are given as reference values to predict Thermal stress in computerized applications.

Keywords: Thermal Transient, Stress, Float Glass, Radiation, FEA

I. Introduction

Window glass damage is caused by *increased*_glass tension, which is caused by rising temperatures in a fire situation. the requires calculations to distribute temperature and calculation of the voltage of the glass in the fire. [1], [2]

Use the latest computational glass model to assess its ability to replicate the rate of damage to the glass. [3] If the glass is suddenly exposed to extreme heat, a shock will cause the glass to break.[2], High-performance building glass that can effectively reduce energy consumption due to thermal and optical properties, increasing thickness can effectively reduce the effects of solar heat radiation and heat transfer coefficients.[4]

The use of glass is limited by its fragility and high strength because it is important to know the study of glass fractures under static and dynamic loads.[5] The acquisition of solar heat radiation from the type of glass that is commonly used has been calculated and in the analysis measured by the measurements tested by solar radiation heat distribution in the room using different types of glass.[6]

Temperature differences can increase with increasing glass thickness. The critical time result and temperature difference are given as reference values to predict the first fracture in an engineering application.[7]

Therefore, the next study was to examine radiation heat, crack time and compare previous studies with the results of simulations to be carried out in this study using Mecway 10 FEA / finite analysis element.

II. Thermal Analysis Theory

The temperature transient thermal analysis and other heat quantities that vary from time to time. The temperature analyzed is calculated as input for thermal stress evaluation; the main difference is that most of the load applied in transient thermal is a function of time.

The finite element analysis (FEA) method on Mecway 10 software was used to analyze the thermal transient and thermal stress on float glass sheets. The finite element method (FEM) is a potential tool for measuring thermal stresses in solid materials, and therefore it is taken to analyze the thermal stress of glass in a fire. For the glass field, the thickness is much smaller in size than the length and width, and then the two dimensions of FEM are taken here. First, the temperature of the glass is calculated and then the thermal stress is calculated based on the temperature. [1].

II.1. Radiation Heat

The formula for radiation heat transfer applies Stefan's law, namely:

$$Qr = e.\,\sigma.\,T^4 \quad (1)$$

In the case of heat flow occurring in one direction $\Delta(T)$ can be written in a simple form.

$$\Delta(T) = (T_1 - T_2)/L \quad (2)$$

So if these units are substituted in the above conditions, there is a thermal conductivity unit *k* as *Watt/m-K.*

$$\Delta Tc = T1 - T3$$
$$\Delta T = T1 - T2 \quad (3)$$

ΔTc is the temperature difference between the center of the fire exposure side and the ambient side, and often more easily available on the glass surface because the temperature in the center is often obtained by thermocouples. [7]

II.2. Yield Stress

In this case, the material is said to begin to melt when the von Mises voltage reaches a critical value known as yield stress. The von Mises stress is used to predict the material decrement rate of loading conditions from the uniaxial simple tensile test results.[8]

$$\sigma = F / Ao \quad (4)$$

Where σ is the stress (Pascal, Nm^2), F is the given load (Newton) and Ao is the initial cross-sectional area (mm^2).

II.3. FEA Simulation Mecway 10 Method

In this method, we analyzed the results of finite element analysis (FEA) on Mecway software by comparing the results of experiment obtained by previous researchers from the publication of Zhang et al, the simulation results will be combined with the experimental results in the following form:

The assembled cabin is 2000 mm × 1000mm × 1000mm, which consists of 5 removable parts with a length of 500mm, 500mm, 500mm, 200mm, 200mm, and 100mm.[7].

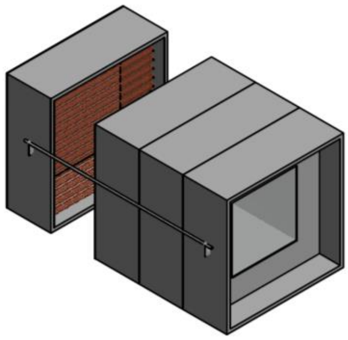

Fig 1 . Glass Heating Cabin

Float glass is used with smooth margins and the size of the glass is 600mm × 600mm. The thickness of the glass used in our experiment is 19mm produced. Glass design uses SNI 15-0047-2005 (*Indonesian national standard*) / BSN (*national standardization body*).[9],[10]

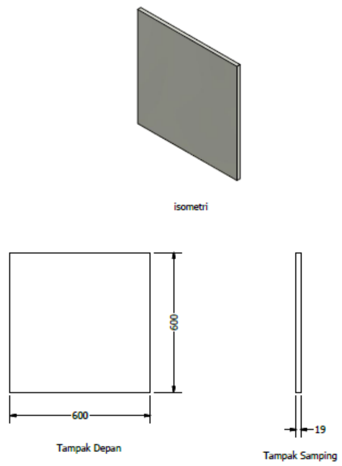

Fig 2. The Dimension of float glass

When the glass is exposed to fire, the heat transfer from the fire to the glass is mainly supplied by radiant heat from heat and convection from the hot gas layer. While the heat transfer in a glass is limited by three basic boundary conditions. The first boundary condition is that the boundary temperature is known, and the second is that the boundary heat flux is known, and the third is that the temperature is fluent in the substance and the heat transfer coefficient is known.

Here the surface of the glass exposed to fire is under the effect of convection and radiation, and then the temperature of the hot gas layer and radiation flux is obtained from the FEA results.[1]

Mecway 10 finite element analysis (FEA) is used to simulate the above test. By comparing temperatures obtained from FEA with those obtained from experiments, FEA results are reliable and then we are used as input parameters for calculating glass temperature in a three-dimensional thermal pressure glass program.

To get perfect results from the thermal stress distribution, the FEA results were compared with experimental experiments. Figure 3 is a graph of the temperature of heat radiation before the surface of the glass at the point given by each one. The locations of points 1 and 2 are shown in Figure 3, which are located at the top and center of the room. It can be seen that the simulated heat radiation temperature is not close to the experimental results but from the graphic form it is very close to the journal and then we are used as input data for calculating glass temperature and thermal stress. At the same time, radiation heat fluxes were also detected in Mecway FEA simulations for calculations.

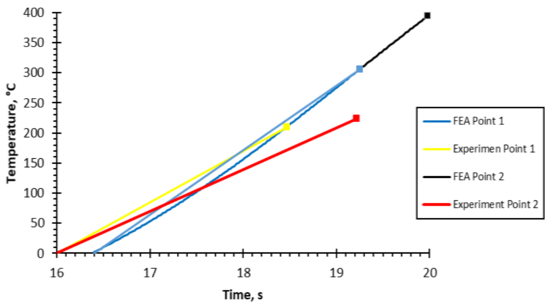

Fig. 3. Comparison of Temperature in Experiments and FEA at the Same Point.

From the results of the graph above it is assumed that the heat obtained from radiation exposure with the same point is also less close to the results of previous experiments.

Because of the glass in the iron frame, the glass is isolated from the heat radiation directly to the surface of the glass and is held on the edge of the glass that is already insulated by the glass frame.

Table 1

PROPERTIES OF FLOAT GLASS IN A SIMULATION. [11].

Properties	Symbol	Value	Unit
Thermal expansion co-efficient	$\mathcal{A}$	9E-06	˚C
Young Modulus	$\mathcal{E}$	70.68	Mpa
Poisson's ratio	$\mathcal{V}$	0.25	--
Emissary	$\mathcal{E}$	0.95	--
Density	$\mathcal{P}$	2500	Kg/ m³
Thermal conductivity	$\mathcal{K}$	0.68	W/m/k
Specific heat	*cp*	250	J/kg.k

Based on Table 1, it can be seen that glass with young modulus, thermal conductivity, emissivity, density, ambient temperature, specific heat, and coefficient heat are most important in the simulation because the properties of float glass material are determined from the values obtained in table 1 so that more clear in the provide of radiant heat and get a yield limit on the glass.

III. Glass Simulation Process

III.1. Thermal Transient

In the simulation of radiation heat at Mecway 10 FEA or finite element analysis, the value of the properties of the float glass material is very important because many float glass is used in the world and especially Indonesia as a building glass in buildings or private homes. And Table 1 shows the parameters imported into the input file before calculation.

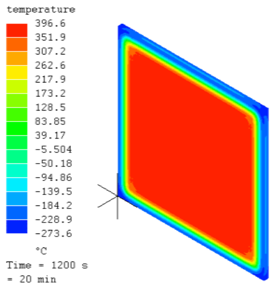

Fig. 4. The highest radiation temperature.

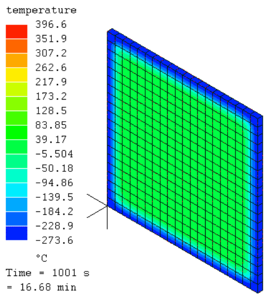

Fig. 5. Variable Temperature Before cracking the glass.

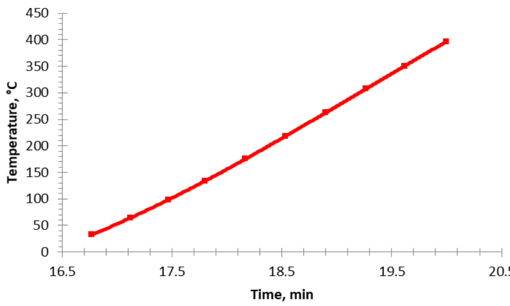

Fig. 6. Main Temperature Distribution.

In the calculation of step-by-step elements, automatic mesh generation is required after the crack. To avoid excessive numerical costs, the right mesh pattern is arranged around the tip of the crack by repairing the crack tip meshes. Only the elements surrounding the crack tip are perfected by a fractal.[12].

From the simulation results on Mecway is shown in Fig. 4 that the temperature of the highest temperature is 396,6 ˚C and the lowest temperature is 39,17 ˚C from ambient temperature in Indonesia approximate approx 32 ˚C, concluded that in this thermal transient simulation influenced by how much time the radiation warms on the glass. From the initial heating source and ambient temperature 32 ˚C to the highest temperature of the starting point of the heater 600 ˚C up to the middle layer of glass 396,6 ˚C. Maximum temperature until the edge of the glass between frames 294.7 ˚C and the minimum temperature is 68,8 ˚C from a warm-up time of 0 to 20 minutes.

Because thermal transient is a thermal transient analysis of temperature and other heat quantities that vary from time to time the radiant heat gradient on glass sheets in Figure 5 and .6 there are variable temperatures before peak heat or glass is damaged from the yield stress limit of the glass namely 39, 17 ˚C to the appropriate temperature the green gradient is 173,2 ˚C in a heating time of approximately 1001 seconds equals 16.68 minutes. In minutes 1147 seconds equal to 19.12 minutes the glass starts experiencing stress / thermal stress from the center of the glass surface with maximum heat 289,4 ˚C and the sides inside the frame/glass frame minimum temperature 39,17 ˚C. seen in the graph that the heat change starts from 16,7 minutes that is 38,65 ˚C and the final heat is 396,58 ˚C.

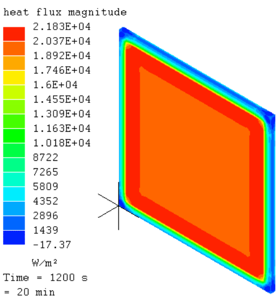

Fig. 7. The flow of Heat Flux at the Time.

The hot flux flow can be seen from figure .7 or with the graph in figure .8 to make it easier for us to analyze the heat flux against the glass sheet which is proportional to the time.

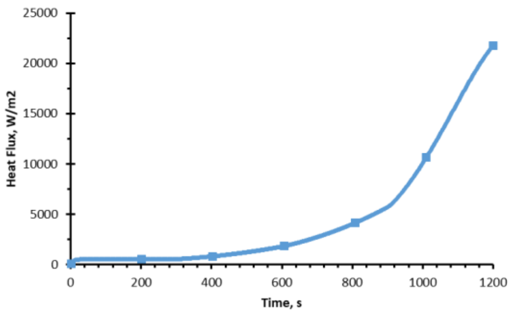

Fig. 8. Heat Flux varies with time.

After observing the next step we analyze the magnitude of heat flux on glass sheets that have been simulated on Mecway FEA, obtained in Fig. 7 and .8 the magnitude of indexed heat fluxes Radiant heat from the front of the glass side exits through the back side of the glass with a minimum heat flux of 20.94 kW / m² in 1198 seconds equal to 19.97 minutes and maximum heat flux of 21.69 kW / m².

III.2. Thermal Stress

In the case of fracture mode, broken glass breaks into large pieces and with a straight and smooth surface fracture.[13]

The thermal stress model is applied with 3D hexagonal 20 (hex20) dimensions to facilitate the determination of nodes and elements in FEA simulation. In this section nodes and elements are used to investigate more detail the effects of various boundary conditions on thermal stress window glass applied to radiant heat.

The results can also serve as verification data for other researchers conducting similar research in the future as there is almost no such data in the literature for fire applications. Experimental data in the literature for glass under fire conditions most of the time for the occurrence of the first crack and glass surface temperature.[14]

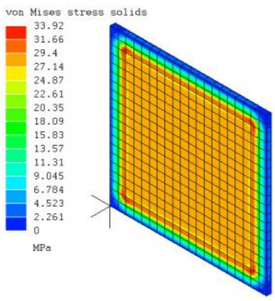

Fig. 9. Variable at Element Value.

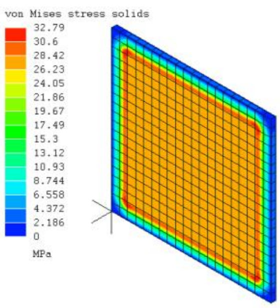

Fig. 10. Variable at Node Value.

Note Figure 10. the initial value in blue indicates the number 0 Mpa means that the part of the frame that is not exposed to heat distribution and is not subjected to stress due to the function to hold the glass also to hold the heat away.

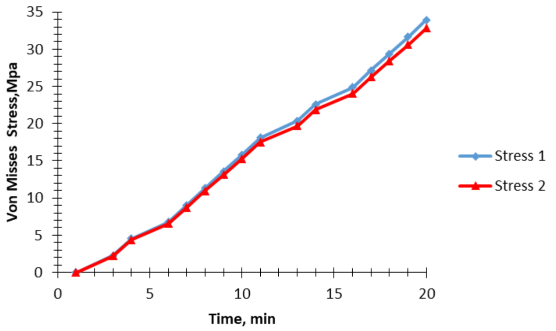

Fig. 11. Two Variable Stress at Time.

Simulation of thermal stress on the glass after transferring from the solution from radiant thermal transient to heat is converted into static 3D in the next analysis to determine the damage to which part will receive stress until finally concluding the first part is exposed to thermal stress distribution, note Fig. 7. There is a variable from FEA, namely von Misses stress for maximum element value is 33.92 Mpa and the minimum is 2.261 Mpa, at the same time which is 20 minutes. In the node value in Fig. 8. the maximum is 32.79 MPa and the minimum is 2.186 MPa from the limit determined by BSN (national standardization body) and (Asahimas). [9],[10] is 34.32 Mpa or equal to 350 kg / cm² to 49.03 Mpa equal to 500 kg / cm².

At the value of the heat, flow node spread throughout the glass from the middle to the edge of the glass frame can be seen from the gradients of blue, green, yellow, orange and red. Red is the biggest stress of the other color gradients shown in Fig.8. The glass undergoes expansion changes can be seen in the orange color of 27.66 MPa, 27.62 MPa to the red color of 28.26 MPa. For the element value, it starts at the middle surface of the glass, the namely orange color is 27.66 Mpa, 27.65 Mpa and the red color is 28.25 Mpa.

It can be assumed that the FEA calculation on node values and element values are more or less equal averaged at 31.32 Mpa, we can see more specific data in the simulation results that have been input to table 2 as below.

Table 2

Heat Simulation at Time and Breakdown Time Parameters

No	Time Step (min)	Temp (c)	Heat Flux	static (Mpa)	Crack Time (s)
1	0	39,17	1.018E + 04	2.261	1011
2	5	173,2	1.455E + 04	11.31	1092
3	10	262,6	1.746E + 04	20.35	1134
4	15	351,9	2.037E + 04	27.14	1177
5	20	396,6	2.183E + 04	33.92	1200

The next analysis is to find out the value of the thermal stress transfer on the glass so that it can be assumed that cracked or broken glass is the maximum value is 0,006242 mm and minimum is around 0,004600 mm of reaction force of 3,235 N and for simplicity, it can be seen in the flow graph and analysis table using the Mecway 10 FEA software.

IV. Analysis Results

The simulation results using FEA / finite analysis elements are used for further investigation by analyzing data output results in the finite analysis element in Mecway 10 software, to be imported into a table and made into a graph plot of various heat and stress conditions. This analysis is important for further verification of nodes and elements in the dimensions of float glass, but also for a better understanding of how these various parameters affect damage to fire conditions.

The results can also serve as verification data for other researchers conducting similar research in the future as there is almost no such data in the literature for fire applications. Experimental data in the literature for glass under fire conditions most of the time for the occurrence of the first crack and glass surface temperature.[14] Thermal stress and thermal transient are validated against Mecway 10 software for simulations with terms of radiation heat and convection. According to the simulation results, it was found that glass panels can break even without shade when the thermal load is large enough.[2]

In the process of giving radiant heat, the number of nodes and elements in the Mecway software application is very influential on the heat treatment process which lasts for 20 minutes, besides the glass used is glass that is often found in buildings in Indonesia, because the price is cheap and easy on could. Therefore, this research is very important to know the strength of glass when it is hot when exposed to fire. And besides that one of the earliest cracks in the middle part if the temperature is perpendicular to the front of the float glass surface, as seen in Figure.4, and because the crack time is the appropriate value for thermal stress and the limit of yield stress determined. We can sea from the Picture image. 9 and Fig. 10, it can be assumed that almost all of the initial cracks occur on the edge of the glass panel or the boundary of the glass frame, where the maximum thermal pressure across the glass and large tension occur between the glass edge and frame. We can sea in the red and orange color gradients. At the time before the first crack, the first stress comes out with the results of the glass strength and stress distribution.

The results of calculations and analysis can help us to determine which cases are relatively safer and provide technical input to the glass. Stress and transient can also be simulated only by changing the thermal properties of the glass type or conditions exposure to radiation changes. This can produce many window designs that are used to verify whether float glass is sufficient for certain software applications specifically in the field of heat simulation on the glass.

V. Conclusion

In this simulation there are cases that we can conclude that float glass is glass that is not good when used in buildings in Indonesia because float glass has very fragile material properties, besides that using FEA simulation on Mecway is very good because all the numbers from the calculation and finite simulation elements are very helpful for data processing, such as making time flow and thermal stress on glass. And we also concluded that the glass after being exposed to radiation heat with maximum temperature 396, 6 ˚C the glass has begun to experience a fracture change where the heat center for the fire extinguisher is around 600˚C with a time difference of 16.7 minutes to 20 minutes. Whereas for thermal stress, float glass gets maximum stress which is 33.92 Mpa. And it can be concluded that the glass that is broken or cracked is the red part of the image.10 or the edge of the glass frame. for more details compared to the images in the previous experimental journal which showed the edge of the glass also cracked with almost the same and similar heat.

It was concluded that the FEA device on Mecway 10 was very helpful in this research and that in the future to minimize damage to the glass and also to pay more attention to the software to be used in the computational simulation because it is very influential when the simulation takes place when the number of nodes, elements and simulation time takes quite a long time.

Acknowledgments

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