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BRILLIABILITY AND FRACTURE STRENGTH OF FLOAT GLASS UNDER STATIC AND DYNAMIC LOADS DUE TO RADIATION HEAT

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ABSTRACT

In this research, steady state and thermal crack analysis was carried out on clear glass exposed to heat radiation with different thicknesses. The analysis process is carried out from the thickness of the glass and testing the temperature variation of the glass testing process to find out the maximum temperature limit of radiation exposure until the glass multiplies thermal crack with steady state analysis of the predetermined ideal heat time. The data collection method used in this study was through testing in an oven where data collection was based on the results of a thermal steady state analysis. The increase in temperature per minute from the first minute was 138.4 ⁰C to the 7th minute or the end was 179.3 °C, from the results research states that in the 7th minute the glass has experienced a crack or crack where the crack starts from the side of the glass which is insulated from radiant heat.

Keywords: steady state; thermal crack; glass fracture; radiation; insulation

1. INTRODUCTION

In countries Glass serves to subdue heat from exposure to sunrays and to maintain indoor temperature so as to not release or hold heat. Glass is also utilized for other purposes, such as in glass material, civil, manufacture and automotive industries [1].

One common type of glass used for windows, tables, doors, cabinets, etc. is float glass. Meanwhile, the automotive world typically employs laminated and tempered glass, both of which help minimize injuries in the event of an accident as they offer higher levels of protection than usual float glass [2][3].

According to Kenny, damage by heat radiation may expose glass structure to concentrated thermal spikes with higher glass composition and atomic ratio [4]. As glass is thermodynamically unstable, it will continue to absorb heat to cool down and stabilize its temperature [5]. Heating and radiation affect the stability and structure of glass in a closed system, and radiation from yielding glass could alter the mechanical properties and structure of the glass [6]. Irregular dispersion is observable for two hours in film glass layers subjected to forced heat treatment of up to 500°C [7].

Heat treatment is a common practice to improve the quality of clarity of glass or glass-like gemstones after melting [8]. Glass damage on buildings stems from increasing glass stress prompted by rising heat in fire situations. Therefore, it is necessary to calculate the temperature distribution and stress of glass during fires [9] [10].

Experiments conducted by Zhang et al. [11] revealed that initial damage on glass with thicknesses of 4mm, 6mm, 10mm and 12mm takes similar time, while that on 19mm-thick glass takes longer. Temperature difference rises in line with increase in glass thickness. Resulting maximum time and temperature gap are used as reference by engineering applications to predict the first fracture [11]. However, research simulations regarding radiation heat on float glass with five thicknesses are still limited, while the dimensions and temperatures of glass in prior studies apply GB11614 standards by using float glass with sizes of 4-19mm x 600mm x 600 mm and heat of up to 600°C.

This study undertook a continuous approach to simulate heat transfer on glass with distributed radiant heat reaching ±600°C at thicknesses of 4 mm to 19 mm according to the national standard (SNI 15-0047-2005) and same sizes as used by Zhang et al [11].

1.1 Characteristics of Glass Types

Clear glass is the most common type of glass used to build a house or building. Usually this type of glass is used as a raw material for windows. It is flat, undistorted, colorless, and can refract objects up to 90%. Its clear form allows sunlight to enter easily into the room. The characteristics of clear glass are:

a. Colorless, clear glass has a very clean, even and distortion-free surface.
b. Due to the nature of colorless glass, this type of glass provides a high transmission rate (over 90%) as well as gives a perfect image.
c. This glass is widely used for the exterior and interior of buildings, both residential and multi-storey buildings because of its low ability to withstand solar heat.
d. This glass can also be used for household furnishings, such as cupboards, table tops, wall decorations, aquariums and so on.

Table 1. Float glass specifications

Item Type	Values
Refractive Index	1.52
Reflectance (Vertical Incidence)	Approx 4% at Each Surface
Specific Heat	0.2 Kcal/kg C (0°-50°C)
Softening Temperatur	720°-730°C
Thermal Conductivity	0.68 kcal/mhr°C
Coefficient Of Linear Expansion	8.5-9 X 10^{-6}/°C (Temp. Normal 350°C)
Hardness	Approx 6 Degrees (Mohs Scale)
Young's Modulus	720.000 kg/cm²
Poisson's Ratio	0.25
Average Breaking Strees	Approx. 500 kg/cm²
Weather Resistance	No Change

1.2 Radiation Heat Transfer

View factor between surfaces that emit and receive radiation (perspective between humans) Heat emission that only occurs in gas or in a vacuum, such as the transmission of solar heat to the earth in a vacuum. To determine the presence of heat emission, an instrument used is a thermoscope. Differential thermoscope is used in investigating the emission properties of various surfaces. An example of radiation is the transfer of heat from sunlight to the earth. Heat radiation can occur if an electric incandescent lamp is lit and a bonfire is lit. Where there is heat radiation emitted by fire.

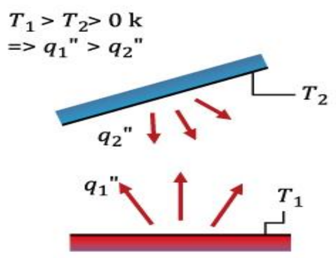

Figure 1. Radiant Heat Transfer

The radiant heat transfer between the absorbing plate and the glass is formulated by:

$$q = \frac{\sigma\ A\ (T_1^4 - T_2^4)}{\frac{1}{\varepsilon 1}+\frac{1}{\varepsilon 2}-1} \quad (1)$$

Where:
q = radiant heat transfer rate (W)
ε = material emissivity
A = surface area (m²)
σ = konstanta Stefan-Boltzmann
(5,67 x 10^{-8} W/m² K^4)
T_1 = surface temperature of the first plane (K)
T_2 = surface temperature of the two planes (K)

Solar radiation that hits the earth's surface also depends on the levels of dust and other pollutant substances in the atmosphere.

Maximum solar energy will reach the earth's surface if the beam of light directly hits the earth's surface because:

a. There is a wider field of view of the incident solar flux.
b. Rays of sunlight travel a shorter distance through the atmosphere, so they absorb less than the angle of incidence is tilted to the normal.

1.3 Steady State

Steady state is a condition when the properties of a system do not change with time or in other words, are constant. This results in that for any property ρ of the system, the partial derivative with respect to time is zero. In most systems, a new steady state will be achieved some time after the system is started or initiated. This initial conduction is often referred to as the transient state. Dynamic equilibrium is a special state of steady state that exists when two or more reversible processes occur at the same rate. However, a system in steady state does not necessarily mean it is in dynamic equilibrium, because some of the processes involved are not reversible processes. For example, the flow of fluid in a pipe or the flow of electricity in a network is a steady state because there is a constant flow of fluid or electricity in it.

Steady state conduction heat transfer in one dimension is the conduction heat transfer that occurs in an object or material. Where the temperature distribution is not a function of time, and the dominant heat energy flow occurs in one direction ignoring other heat energy flow directions isolated. Steady conduction heat transfer is calculated in the following equation:

$$qx + q\ Adx = qx + dx\ \rho Adx\ \frac{\partial u}{\partial t} \quad (2)$$

Where:
qx = conduction heat transfer rate (J/s)
q = generated heat energy (J)
Adx = volume (m³)
ρAdx = volume mass (kg)
$\frac{\partial u}{\partial t}$ = rate of change of energy volume mass

1.4 Thermal Stress

In mechanics and thermodynamics, thermal stress is the mechanical stress caused by a change in the temperature of a material. These stresses can cause fractures or plastic deformation depending on other heating variables, which include material type and boundaries. Temperature gradients, thermal expansion or contraction, and thermal shock are things that can cause thermal stress. This type of stress is highly dependent on the coefficient of thermal expansion which varies from material to material. In general, the greater the temperature change, the higher the stress level that can occur. Thermal shock can occur as a result of rapid temperature changes, resulting in cracks or breaks.

$$SC = \frac{P}{A} \quad (3)$$

Where:
SC = thermal stress (MPa)
P = hot pressure (N)
A = area (m²)

According to research by Zhang et al., it was stated that after exposure to radiant heat reached a peak or a maximum of 1 minute and was held for 20 minutes until the glass was declared not to have deformed due to heat stress. The existence of a temperature gradient inside the glass will cause the heat transfer rate to be calculated by the following formula:

$$Q = -\ k.A.\frac{\Delta T}{\Delta x} \quad (4)$$

Where:
Q = heat transfer rate (J/s)
k = material thermal conductivity (W/Mk)
A = cross-sectional area of the material (m²)
ΔT= temperature difference between the metal ends (K)
Δx = material length or width (m)

2. METHODS

At this stage the research was carried out by designing a model based on observations and measurements from previous experimental results on exposure to radiant heat of float glass which is used as a property of the flat glass material to be tested.

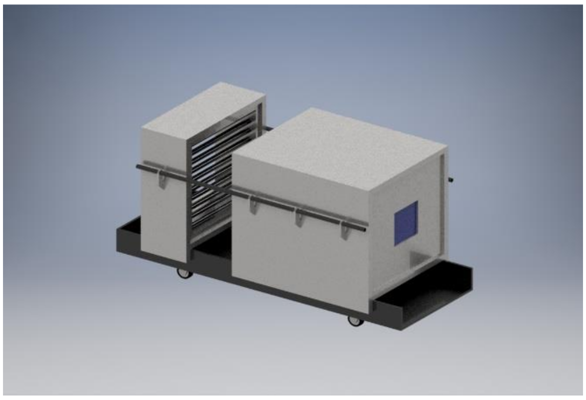

Figure 2. Oven design

The planning data for the design of the oven are as follows:

a. Oven height 100 cm
b. The width of the oven is 100 cm
c. Oven length 200 cm
d. The thickness of the float glass is 5 mm
e. Clear glass size 30 x 30
f. The walls of the oven use zinc plates
g. The heating element uses a dry heater
h. The temperature used is 300 °C
i. Testing time is 30 minutes
j. Thermostats
k. Heaters
l. Wheels 4 pieces
m. Thermocouples
n. 2 pieces of angle iron 30x30 cm x 30 mm

2.1 Frame design

The process of assembling the oven tool after preparing the tool is followed by making the frame.

Here is the process of making the frame:

a. Holo iron cutting with a size of 3x3 and zinc plate with a thickness of 0.5 mm
b. Size 100 cm as much as 11 sticks
c. Size 200 cm as much as 4 sticks
d. Size 250 cm as much as 2 sticks
e. Size 100x100 cm as many as 4 sheets
f. Size 180x100x30 cm 4 sheets

2.2 Research design

In this research, steady state and thermal crack analysis was carried out on clear glass exposed to heat radiation with different thicknesses. Furthermore, a technical feasibility analysis and analytical calculations were carried out from various data with an experimental design. The analysis process is carried out from the thickness of the glass and testing the temperature variation of the glass testing process to find out the maximum temperature limit of radiation exposure until the glass multiplies thermal crack with steady state analysis of the predetermined ideal heat time.

2.3 Data collection

The data collection method used in this study is through testing in the oven where data collection is based on the results of a thermal steady state analysis.

2.4 Analysis design

The data analysis used in this study is where the numbers shown on the results of the flat glass test are presented. The data analyzed are the numbers obtained from the results of the steady heat test on radiation exposure and 20 minutes of time. This form of data analysis will show the strengths and weaknesses of the thickness variation of the glass dimensional design that has been carried out.

3. RESULTS AND DISCUTIONS

3.1 Analysis and calculations

The temperature of the clear float glass test results in minute research can be seen in table 2. On clear glass at maxsimal temperature at T1 is 179.3 °C, T2 = 124.8 °C, T3 = 99.4 °C, T4 = 122.6 °C, in the same minute that is 7 minutes.

Table 2. The temperature of the clear float glass test results per minute

Time/minute	Heat			
	T_1	T_2	T_3	T_4
17:50	138,4˚C	96,1˚C	37,1˚C	86,8˚C
17:51	144,5˚C	98,4˚C	38,4˚C	88,7˚C
17:52	152,1˚C	105,7˚C	57,8˚C	91,6˚C
17:53	156,9˚C	109,8˚C	58,9˚C	107,8˚C
17:54	160,7˚C	118,0˚C	70,1˚C	109,1˚C
17:55	168,1˚C	119,7˚C	71,4˚C	117,4˚C
17:56	173,9˚C	123,9˚C	80,5˚C	120,0˚C
17:57	179,3˚C	124,8˚C	99,4˚C	122,6˚C

Based on the results, it is explained that there is a very clear difference between the initial heating time until the end of heating until the glass is declared broken or by determining the maximum heat on the surface and inside the dimensions of solid glass by providing radiant heat and convection from a fire extinguisher or panel perpendicular to glass wall so that the glass absorbs heat and heat transfer occurs from the temperature of the front surface to the back surface until the glass experiences stress or tension which causes the float glass to experience thermal stress and thermal shock, based on a comparison of temperatures and variations of different glass thicknesses for continuous glass heat treatment continuously / transients have increased and obtained an average temperature value during the process with the thinnest glass 5 mm with a maximum temperature of 160.7˚C from ambient or ambient temperature of 32 ˚C, after conducting experiments from transient to thermal steady state to find out the temperature and heat transfer from the center of the glass to the edges of the insulated glass within the glass frame to keep the heat from escaping.

Table 3. The highest temperature occurs cracks on clear glass

Thickness (mm)	Heat crack	Times	Heat			
			T_1	T_2	T_3	T_4
5	179,3˚C	480	179.3˚C	124,8˚C	99,4˚C	122˚C

It can be seen in the table 3 that the highest temperature and the highest temperature fracture occurred at 179.3 °C with a thickness of 5 mm and a time of 480 seconds or 7 minutes.

Table 4. Results of the temperature cracking test on clear float glass

Thickness (mm)	Time (s)	ΔT_C (˚c)	ΔT (˚c)
5	480	79,9	54,5
	420	93	49,6
	360	96,7	48,4
	300	90,6	42,7
	240	98	47,1
	180	94,3	46,4
	120	106,1	46,1
	60	101,3	42,3

The temperature for cracking on clear glass in 60 seconds ΔTC is 101.3°C, ΔT is 42.3 °C, as shown in table 4.

4. CONCLUSION

From the various studies above, it can be concluded that clear glass cracks measuring 5 mm with a size of 200 x 200 cm were successfully heated through a furnace at a radiation temperature on the windshield surface of 174.3°C and the outer glass surface of 124.8°C, with a hot testing temperature specific, namely ΔT C = 79.9°C and ΔT = 54.5°C at 480 seconds. The thermal stress of 5 mm float glass has a maximum stress of 34.69 MPa and is in accordance with the yield stress limit given by SNI. Compared with the results of previous experiments which showed the edge of the glass cracked.

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