EVENT BASED MODELING AND ANALYSIS FOR GLASS TEMPERING PROCESS

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Abstract: *In this paper Glass tempering process elaborates that how Glass is tempered with step by step process. The Glass Tempering Process helps to increase certain characteristics such as strength, transparency, durability, harness of the processed glass.. Glass tempering process is simulated using Petrinet simulation tool and the simulation results are validated by analytical and graphical methods. Analytical method used in this paper is invariant analysis and graphical methods used are evolution graph and Reachability graph.*

Keywords: *Hybrid petrinets, modeling, petrinets, simulation.*

1. Introduction

The Glass tempering process was studied asaki glass plant in chennai ,based on the study the glass tempering process is modeled using hybrid Petrinet software. This model is used to study the behavior of system and find any fault diagnosis in the process. Through this model new controller can be designed and also response speed of the process can be increased.

2. Hybrid Petrinet:

There are two types of nodes in Petrinet Places ,Transistions and Arc. Places represented by circle and denoted as P_1. Transitions represented by Rectacle and denoted as T_1

N= (P,T,pre,post,m) (1)

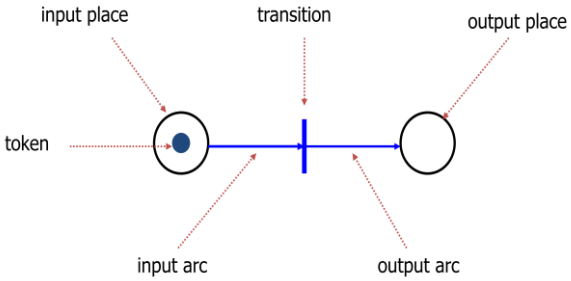


Fig 1. Block Diagram of Petrinet

$$m_k = m_i + w.s \quad (2)$$

$$\mathbf{W = (W^-) + (W^+)} \quad (3)$$

3. Process modeling and analysis

The figure shows Block diagram of Glass Tempering process.

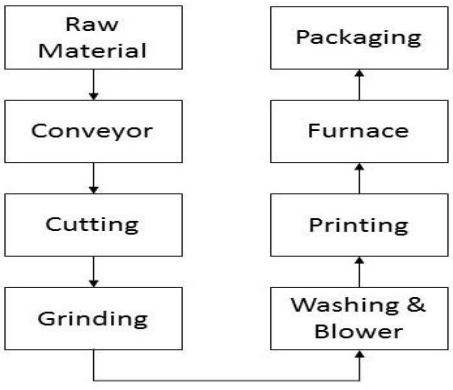


Fig 2. Block Diagram of Glass Tempering Process

Raw material

Raw material used is manufactured glass sheet. The step by step process are involved to tempering the glass

Conveyor

The raw materials are moved to the cutting section through the conveyor

Cutting

The cutting of glass is done using glass cutter. The Glass cutter makes score on the surface of glass where it is to be cut. The glass breaks along the score

Grinding

In this stage Polishing and smoothing the glass edge is done.

Washing and blower

At this stage washing of glass is done using forced water spray. This gives the glass clear texture.Blowing of air s done in order to absorb moisture on glass.

Printing

In this stage glass border to drill holes the lines are printed in the glass. Te glass also made UV resistance..

Furnace

The furnaces are maintained at constant temperature for Tempering the glass ,. The fuels using for furnaces are natural gas- or fuel oil-fired,

Packaging

The final stage is inspection of glass for testing quality like scratch, bubble, cullet, white spot, breakage, powder mark, etc. After passing Quality check. W-Threads are used for packing the glass.

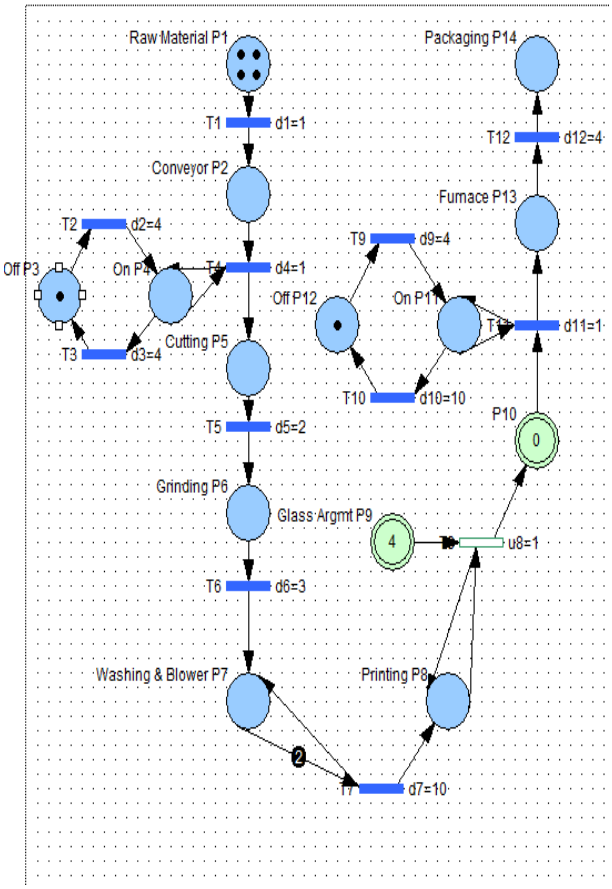


Fig.2: Simulation diagram using petrinet

Table1: Places with their corresponding logic

Places	Representation
P1	Raw Materials
P2	Conveyor
P3, P4	Valve On/Off
P5	Cutting
P6	Grinding
P7	Washing and Blower
P8	Printing
P9, P10	Glass Arrangement
P11, P12	Furnace valve ON/OFF
P13	Furnace
P14	Packaging

The algorithm is explained as follows:
There are 14 places and 12 transitions in this modeling. every places is connected to discrete or continuous transitions so called as constant duration constant maximal speed..

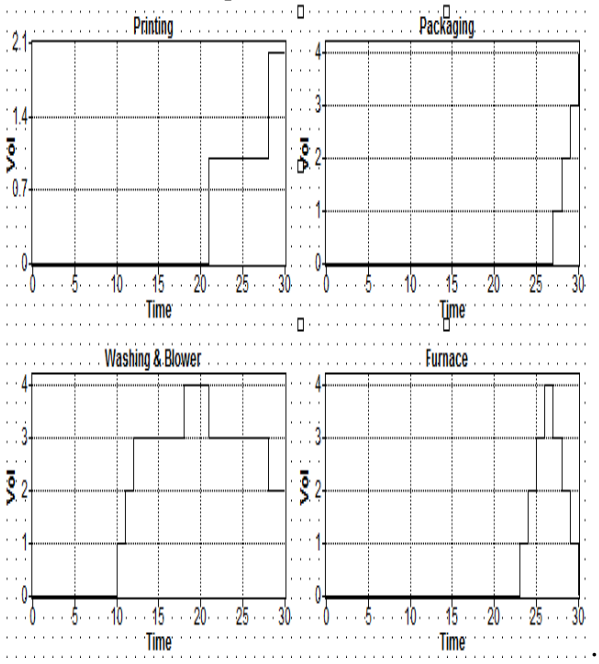


Fig 2. Simulation response of glass tempering process at firng 26

In the figure 2, at 26th firing, the one token in place P13 fires into place P14. Now there are 4 tokens placed inside in packaging. It denotes that 4 raw materials taken as token had undergone various process and finally reached as 4 token in the packaging section. The 4 glass materials are finally packed and dispatched. The graph denotes that all 4 glass materials taken as raw material has received the packaging stage and it is packed and dispatched to customer.

4. Validation of Simulation Results

4.1. Mathematical Analysis

For a Petri Net model, equation is given as,

$$m_k = m_i + w.s$$

In the above equation W is represented as multiplier. It is used to multiply firing angel 'S'. with Pre-condition $W_{(PRE)}^-$ and the post-condition $W_{(POST)}^+$. It is also denoted as A_i and A_O instead of Pre-condition and Post-condition respectively. [1]

For this invariant analysis the required values from each stage of firing has been noted down.It is used to form a matrix to analysis the process. The input(A_i) or Pre-condition matrix and output (A_o) or Post-condition matrix has been derived with these noted values and plotted below. These matrices are used to calculate the Incidence matrix (A).

Input Matrix:

A_i (12 x 14)

$W_{(PRE)}^-$= **Input Matrix:**

A_i (12 x 14)

$W_{(PRE)}^-$=

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T4	0	1	0	1	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	2	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T10	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T11	0	0	0	0	0	0	0	0	0	1	1	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Before each firing stage each matrices calculated The input matrix consists of transitions are 12 and places are 14. The places P1 To P14 in the column and transitions T1 to T12 in the row in the matrix.

Output Matrix:

A_0 (12 x 14)

$W_{(POST)}^{+}$ =

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	1	1	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	1	1	0	0	0	0	0	0
T8	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	1	0	1	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1

When the marking 1 is indicated in row 12 and column 14 .it is indicated that the process is completed .

Incidence Matrix:

A (12 x 14)

$W = W_{(POST)}^{+} - W_{(PRE)}^{-}$

W =

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	-1	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	1	-1	0	0	0	0	0	0	0	0	0	0
T4	0	-1	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	-1	1	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	-1	1	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	-1	1	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	-1	1	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	1	-1	0	0
T10	0	0	0	0	0	0	0	0	0	0	-1	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	-1	0	0	1	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	-1	1

In the following equation W is represented as multiplier. It is used to multiply firing angel 'S'. with Pre-condition $W_{(PRE)}^{-}$ and the post-condition $W_{(POST)}^{+}$. It is also denoted as A_i and A_O instead of Pre-condition and Post-condition respectively.

From the fundamental equation:

$M_k = M_i + W.S$

Where,

M_k represents input matrix

M_i represents output matrix

W represents incidence matrix

S represents transition state

M26 = 0 0 0 1 0 0 2 2 0 0 0 1 1 3

S26 = 0 0 0 0 0 0 0 0 0 0 0 0 0 1

W*S26 = 0 0 0 0 0 0 0 0 0 0 0 0 -1 1

M27 = 0 0 0 1 0 0 2 2 0 0 0 1 0 4

5. Evolution graph

. The Evolution graph gives pictorial representation of previous , current and future information of the process

The places P1, P3, P9, P12 having values 4,1,4,1 respectively which denotes the number of tokens in the raw material, valve 1, Glass arrangement, Valve 2 correspondingly. The places having the value zero represents nil number of tokens in the corresponding stages.

First Firing (T=1sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
1	0	0	0	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	4	1	0	0	0	0	0	4	0	0	1	0	0

In this firing the raw material transfer to second stage conveyor P2 through the transition T1.

Second Firing (T=2sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	1	0	1	2	3	10	0	1	10	0	4

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	4	0	1	0	0	0	0	4	0	1	0	0	0

In this firing valve 1 and valve 2 gets on, Thus the raw material flows into the following stages. Transition occurs based on the time taken and the weightage of the arc. Since both the valve gets on the flow continues its transition until both valve turned off.

Third Firing (T=3sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	1	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	4	0	1	1	0	0	0	4	0	1	0	0	0

In this firing one glass enters the stage P5

through the transition T4.In the next firing another glass enters into the stage P5 through the transition T4.

Fourth Firing (T=4sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	1	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	2	0	1	2	0	0	0	4	0	1	0	0	0

Fifth Firing (T=5sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	1	1	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	0	1	2	1	0	0	4	0	1	0	0	0

By FIFO technique, first incoming glass enters into the next stage grinding P6 through the transition T5.

Sixth Firing (T=6sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	1	0	1	1	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	1	0	1	2	0	0	4	0	1	0	0	0

The valve turns OFF, simultaneously second glass enters into the stage P6. The valve continues to be in OFF stage the another glass enters in to P6 through T5.

Seventh Firing (T=7sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	1	1	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	1	0	1	3	0	0	4	0	1	0	0	0

Eighth Firing (T=8sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	1	1	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	1	0	0	2	1	0	4	0	1	0	0	0

The first entered glass, now enters into the washing and blower P7 through the transition T6.

Ninth Firing (T=9sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	1	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	1	0	0	1	2	0	4	0	1	0	0	0

Following the previous firing next glass enter in to P7 through the transition T6. Last glass is still waiting in the stage P2, it enters to the following stage only on next firing. In 10th firing valve 1 turns on, thus three glass comes under stage P7.

Tenth Firing (T=10sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	1	0	1	1	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	1	0	1	0	0	3	0	4	0	1	0	0	0

Eleventh Firing (T=11sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
1	0	0	1	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	1	0	3	0	4	0	1	0	0	0

In this stage final glass enters into P5, valve V1 and valve V2 are still in ON state. In 12th firing Valve 2 turns OFF through the transition T10.

Twelfth Firing (T=12sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	0	1	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	1	0	3	0	4	0	0	1	0	0

Thirteenth Firing (T=13sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	1	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	1	3	0	4	0	0	1	0	0

In this firing last glass entered into P6 through the transition T5.

Fourteenth Firing (T=14sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	1	0	0	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	1	3	0	4	0	0	1	0	0

In this firing valve V1 turns OFF, through the transition T3. In 15th firing valve V2 turns ON, correspondingly all the glass comes under the stage P7.

Fifteenth Firing (T=15sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	1	0	0	0	1	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	0	4	0	4	0	1	0	0	0

Sixteenth Firing (T=16sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	1	0	0	0	0	0	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	4	0	4	0	1	0	0	0

In this firing valve V1 turns ON through the T2 with timedelayof4sec.

Seventeenth Firing (T=17sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	1	1	0	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	3	1	4	0	1	0	0	0

First glass enters the stage P8 through the transition T7.

Eighteenth Firing (T=18sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	1	0	0	0	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	3	1	3	1	1	0	0	0

Following the previous stage place P9 denotes the glass arrangement start reducing in its value when each glass enters the previous stage.

Nineteenth Firing (T=19sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	1	0	0	1	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	3	1	2	1	1	0	1	0

As each glass crosses the P8, it then comes under the furnace stage P13.

Twentieth Firing (T=20sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	1	0	0	0	0	1	0	0	1	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	0	3	1	1	1	1	0	2	0

In this firing two glass enters the stage P13 through the transition T11. At the same time valve Turns OFF. At 21st firing three glass enters into the stage P13 through the transition T11. Thus P9 indicate 0, which represents that all the glass crosses stage P8.

Twenty First Firing (T=21sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	1	0	0	1	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	0	3	1	0	1	1	0	3	0

Twenty Second Firing (T=22sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	0	0	0	1	0

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	0	3	1	0	0	1	0	4	0

In this firing all the glass comes under furnace P13. Place P7 having three tokens denotes three glass crossed the stage P10. In 23rd firing first glass enters into the final stage P14 through the transition T12.

Twenty Third Firing (T=23sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	0	0	0	1	1

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	1	0	0	0	3	1	0	0	1	0	3	1

Twenty Fourth (T=24sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	1	0	0	0	0	1	1	0	1	0	1

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	2	2	0	0	0	1	2	2

In 24th firing valve V2 turns OFF. Since all the glasses crossed the printing stage. Here two glasses are in P13 and two glasses are in P14.

Twenty Fifth Firing (T=25sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	0	0	0	0	1

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	2	2	0	0	0	1	1	3

In 25th firing, Third glass enter into the P14 and only one glass left in P13.

Twenty Sixth Firing (T=26sec)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
0	0	0	0	0	0	0	0	0	0	0	1

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
0	0	0	1	0	0	2	2	0	0	0	1	0	4

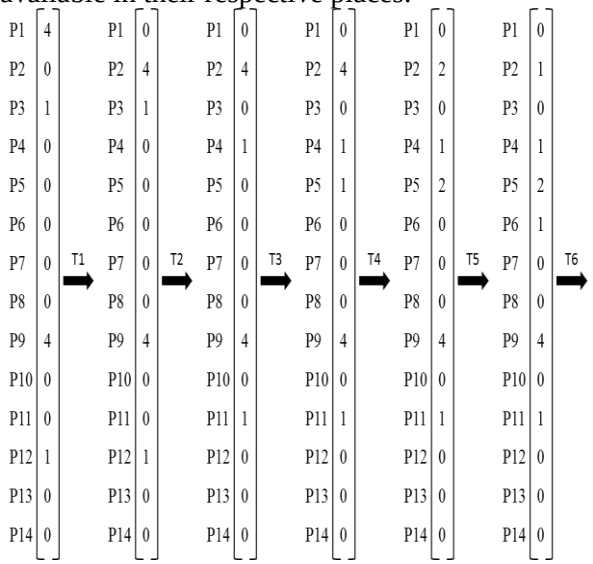
In this firing all the four glass, comes into final stage P14 for packaging. Two tokens in P7 and P8 represents sensed value of four glasses that crossed over every stage. In the above mentioned

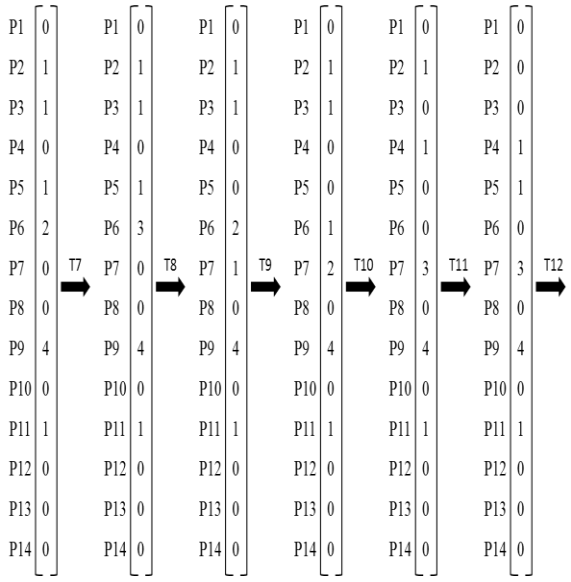
evolution graph, it is mentioned that values assigned to all places at each firing. In our process the final stage of process is achieved in 26th transition.

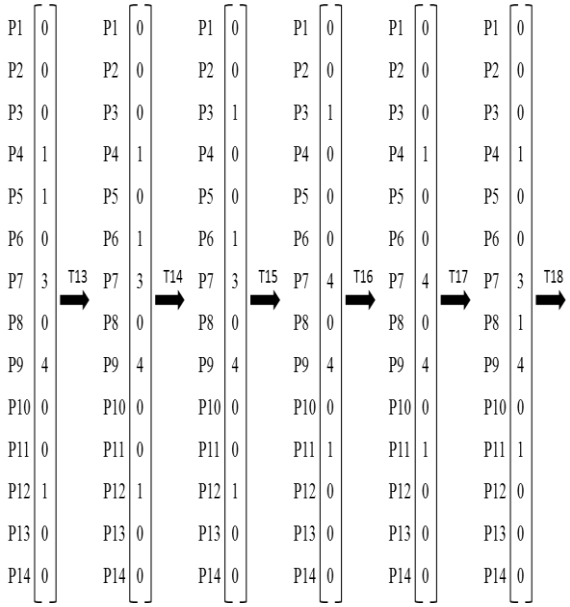
6.0 Reachability graph

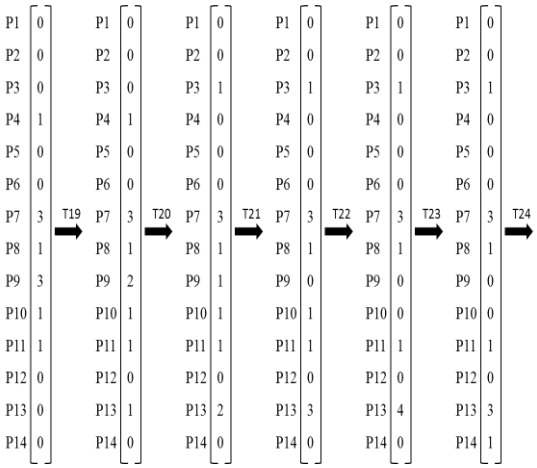
The Reachability graph gives pictorial representation of previous , current and future information of the process.

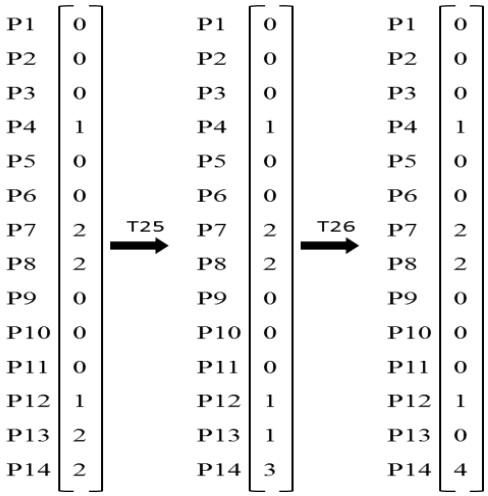
The places is marked in x axis . the transistion marked in Y axis.. This graph shows that from first firing to fifth firing, the tokens are available in their respective places.











The above given graph shows that from twenty fourth firing to twenty sixth firing, the tokens are available in their respective places. First row shows the matrix value after the twenty fourth

transition. Similarly, the second and third row shows the values after twenty fifth and twenty sixth transitions respectively.

7. Conclusion:

Hybrid petrinet is a new technique used to simulate the Glass Tempering process , the glass tempering process is simulated using sirphyco software, using petri nets. The simulation results are evaluated by three methods 1.Invariant Analaysis, 2.Evolution Graoh and. 3. Reachability graph. Hence both simulation and evaluation results are proved to be same .In future hybrid controller will be designed to control the glass tempering process

References

[1] Rene, D.,and Alla ,H., Discrete,continuous and hybrid petrinets. NY:springer-verlagberlin, Heidelberg,nov.2004.

[2] Ranganathan,K.,and bhaskar,V.,''Perfrmance evaluation and model checking in systems modeled as hybrid petrinets ,''Journal of Applied Mathemetical Modeling, article in press,2011 [3]

[3] Guia, A., Pilloni, M. T.,and seatzu, c.,''modeling and simulation of a bottling plant using hybrid petri nets'', International Journal of Production Research,vol.43,no.7,pp.1375-1395,July 2005

[4] Ghomri,L., and Alla, H.,'' Modeling and analysis using hybrid petri nets, 'nonlinear analysis: hybrid system,vol.1 no.2,pp.141-153,June 2007.

[5] Svadoa,M.,''Modeling hybrid dynamic systems using hybrid petri nets,''proceedings of the 13th International conference on process control,Bratislava,Slovakia,June2001

[6] Solis, F.,and vargas,H.,''A hybrid approach combining petrinets and product lifecycle management to simulate determine and validate the performance of flexible manufacturing systems,''IEEE International Conference on Information Society (i-Society),london,UK,pp.598-603 June 2010

[7] Murata, T 1989, 'Petri nets: Properties, analysis and applications', in Proc. IEEE, vol. 77, no. 4, pp. 541-580.

[8] Muthuraj. B, Mahesh, V & Senthil, R 2016, A HybridPetri Net Approach for Polyethylene Terephthalate Bottle Manufacturing System', Journal of Computational and Theoretical Nanoscience. Vol.13,no.7,pp.4557-4561.

[9] Muthuraj B, Uma M , Shanmuga Priya R 2017, Hybrid Petri Net Approach for Batch Process,' International Journal for Research in Applied Science & Engineering Technology. Volume 5 Issue III, March 2017 ISSN: 2321-9653 March2017

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Solis, F.,and vargas,H.,''A hybrid approach co