Presentation of Autoclot: calculation and drawings of tracks for guided transport systems

C. Thatcher
Head of CAD Design Department, SEMALY, France

Abstract

SEMALY, a consulting company in Public Transportation has produced software in 1997 for designing tramway alignment especially in city centres where the lack of space and the integration of the tramway are very important. The software takes into account the geometrical parameters of the rolling stock as well as the parameters of comfort of the alignment. The technician will define the radius and the straight alignments he needs in Autocad according to the environment, and the software will automatically draw the whole platform (with one or two tracks) with DKEs, axes, transition curves, extra widths of the DKEs in the curve and will calculate the speed and comfort parameters along the alignment. The alignment will be automatically optimised in order to have the minimum clearances between swept paths in curves and in straight alignments.

1 Introduction

Autoclot is software designed by SEMALY, used initially in 1997 in order to help designing track alignment for the tramways in Lyons, Grenoble and Montpellier.

Indeed the existing softwares on the market are more based either on road alignment or on railway alignment but there was no product specific for urban trams. Autoclot is now used on every tram project in SEMALY, from preliminary design to detailed design. The main references of this software are trams in Lyons, Grenoble, Strasbourg, Oporto, Dublin that are presently under operation. Autoclot was used recently on many tram projects outside France (Edinburgh, Lisbon, London) and in Israel (Jerusalem, Tel Aviv).
2 Comfort parameters for tram alignment design

The main parameters in tram alignment design are:

- **Transversal acceleration (in m²/s)**

  Gmax is the transversal acceleration.
  (usually Gmax = 0.68 m/s²)
  S : speed of the tram
  E : distance between the rails
  (usually E = 1435 mm)
  d : cant
  \[ Gmax = G2 - G1 \]
  \[ G2 = S^2 / R \]
  \[ G1 = g \times \tan a \]
  a is given by the cant d of the track.
  \[ \tan a = d / E \]
  \[ S^2 / R - g \times d / E < Gmax \]

- **Variation of transversal acceleration (jerk, in m³/s)**

  \[ dGmax / dt < \text{Jerk max} \]
  (usually Jerk max = 0.4 m/s³)

  The variation of transversal acceleration is occurring in the transition curves, between the straight alignment and the circle.

- **Variation of cant (in mm/m)**

  Limiting the variation of cant enables to avoid twisting the body of the tram.

- **Vertical speed of the rail (in mm/s)**
• Maximum speed of the tram
• Minimum horizontal radius
These parameters can be defined in Autoclot for each project. They can be changed according to the ratio comfort/speed each project reaches to.

3 Transition curves.

Transition curves are usually clothoids (equation $1/R = k \times s$, with $R$ the instant radius on the curve, $K$ a constant and $s$ the chainage on the curve).

Clothoids enable the constant variation of transversal acceleration between the straight alignment and the radius.

![Figure 2: Representation of a clothoid.](image)

Autoclot draws clothoids but also other transition curves like Oves (section of clothoid joining two non secant circles) or C curves (section of clothoid joining two secant circles).

4 Geometrical parameters for tram alignment design

The swept path of trams in curves is wider than the swept path in straight alignment because of the geometry of the tram body. Moreover, cant, location of catenary poles, minimum clearances have an impact on the width of the track. Autoclot optimises this width and calculates the swept path lines taking into account the following parameters:
• The width of the tram.
• The extra width of the body in curves (a table can be entered with specific widths according to curves. The software calculates the intermediate widths).
<table>
<thead>
<tr>
<th>Radius (m)</th>
<th>Distance Axis - Exterior Swept Path Line (m) (B)</th>
<th>Distance Axis - Interior Swept Path Line (m) (C)</th>
<th>Distance between axes (m) (D)</th>
<th>Interior extra width (m)</th>
<th>Exterior extra width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>2.330</td>
<td>1.935</td>
<td>4.015</td>
<td>0.695</td>
<td>0.218</td>
</tr>
<tr>
<td>30</td>
<td>2.245</td>
<td>1.885</td>
<td>3.860</td>
<td>0.520</td>
<td>0.166</td>
</tr>
<tr>
<td>40</td>
<td>2.135</td>
<td>1.830</td>
<td>3.715</td>
<td>0.410</td>
<td>0.105</td>
</tr>
<tr>
<td>50</td>
<td>2.070</td>
<td>1.795</td>
<td>3.615</td>
<td>0.345</td>
<td>0.070</td>
</tr>
<tr>
<td>60</td>
<td>1.965</td>
<td>1.745</td>
<td>3.460</td>
<td>0.240</td>
<td>0.020</td>
</tr>
<tr>
<td>70</td>
<td>1.935</td>
<td>1.730</td>
<td>3.410</td>
<td>0.205</td>
<td>0.005</td>
</tr>
<tr>
<td>80</td>
<td>1.860</td>
<td>1.730</td>
<td>3.340</td>
<td>0.135</td>
<td>0.005</td>
</tr>
<tr>
<td>90</td>
<td>1.760</td>
<td>1.727</td>
<td>3.277</td>
<td>0.075</td>
<td>0.002</td>
</tr>
<tr>
<td>100</td>
<td>1.705</td>
<td>1.727</td>
<td>3.242</td>
<td>0.040</td>
<td>0.002</td>
</tr>
<tr>
<td>150</td>
<td>1.735</td>
<td>1.727</td>
<td>3.222</td>
<td>0.020</td>
<td>0.002</td>
</tr>
<tr>
<td>200</td>
<td>1.725</td>
<td>1.725</td>
<td>3.200</td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>250</td>
<td>1.725</td>
<td>1.725</td>
<td>3.200</td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>500</td>
<td>1.725</td>
<td>1.725</td>
<td>3.200</td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>1000</td>
<td>1.725</td>
<td>1.725</td>
<td>3.200</td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>2000</td>
<td>1.725</td>
<td>1.725</td>
<td>3.200</td>
<td>0.000</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Figure 3: Example of extra widths table for Autoclot (Edinburgh tram).

![Diagram](image)

Figure 4: Definition of extra widths in curves.

- The exterior and interior offset of variation of the DKE compared to the tangent points
- The height of the vehicle (important for cants)
- The clearances between DKEs (interior and exterior)
- The clearance between de DKE and the Swept Path Lines (SPL).

Autoclot enables to chose the rolling stock with its geometrical characteristics in a pre-defined list.
5 Using Autoclot

Once the parameters of comfort and of geometry are defined, the technician designs the centre line of either both tracks or a single track, called the “nominal axis”. This design of the nominal axis is made directly in Autocad, with CAD lines and circles tangent to each other. By using defined blocks, the technician can set cant and specific distances between tracks (for centre poles for example).

After choosing the different options for the layout, the technician clicks on the nominal axis that directly starts the drawing of the different swept paths.
Autoclot enables to draw directly the centre lines of both tracks or a single track with transition curves and DKEs.

It is possible to choose either the automatic calculation (optimised alignment for maximum speed) or the manual calculation (for specific lengths of clothoids in difficult topographical constraints).

It is thus possible to optimise the length of clothoids according to the available space and to the resulting speed.

6 Autoclot Alignment layout

Autoclot draws the swept path of the track and gives automatically tables on each track of the curve with the following information:

- Radius of the track axis (defined by the technician on the nominal axis)
- Real cant
- Length of Entry Clothoid
- Parameter of Entry Clothoid
- Length of Circle
- Length of Exit Clothoid
- Parameter of Exit Clothoid
- Maximum speed in curve
• Transversal acceleration in curve
• Jerk in curve

7 Exports

It is possible to export the Autoclot axis to many alignment softwares on the market like MX (MOSS), PISTE (French software), or other for designing the long section for example.

Moreover, implantation tables can be generated in text format for editing of using in Excel for example.

A special export file has been created for producing speed and timetables. These tables give the speed and the time spent by the tram along the alignment, taking into account the alignment characteristics form Autoclot but also the road junctions, the environment of the tram (level of track segregation for example), the location of stops.

Figure 8: Oporto tram in a curve designed with Autoclot.

References

The software Autoclot has been used on many projects since 1997 by SEMALY in feasibility studies, detailed design and for construction drawings. The main references are the following:

Construction drawings:
• Lyons Tram (Line 1, Line 2, 2000, 25 km)
• Oporto Tram (1999, 70 km)
• Montpellier Tram (2000, 18 km)
Grenoble Tram (1999, 17 km)

Detailed Design:
- Lyon airport Tram-Train Line (2004, 18 km)
- Jerusalem Tram (2001, 16 km)
- Tel Aviv Tram Green Line (2000, 18 km)
- Marseille Tram (2004, 15 km)
- Dublin Tram (1998, 16 km)

Feasibility Studies:
- Edinburgh Tram Line 2 (2003, 19 km)
- West London Transit (2003, 15 km)
- Velizy Tram on Tyre (2002, 13 km)
- La Rochelle Guided Bus (2001, 9 km)