University of BRISTOL

Department of Mechanical Engineering

VIRTUAL PRODUCT DEVELOPMENT (MENGM6049) - Lecture 4 Curve Analysis 2017-2018

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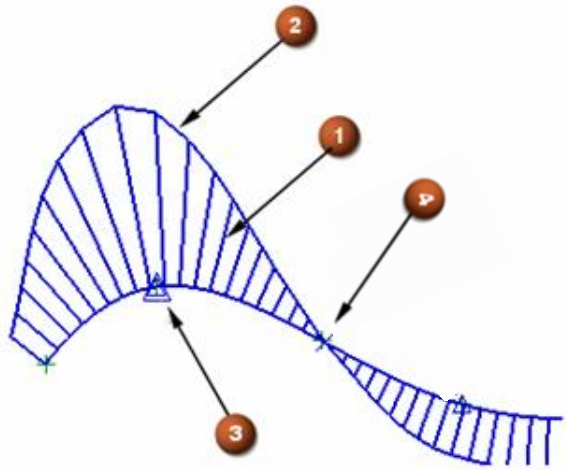
The Purpose of the Lecture

- Give you an understanding of what a curvature & curvature plot is.
- The use of curvature plots to display and interrogate/analyse the characteristics of curves such as Curvature Comb, Curve Continuity, Peak and Inflection Points, curve Poles.
- What is an inflection point and its importance in designing fair or smooth engineering curve.
- What is a continuity when two splines are joined together as a composite curve and why it is important when designing a complex shape.
- Examples of curve continuity, fair/smooth curve and curvature plot information.

Curve/Spline Analysis using Curvature Plots

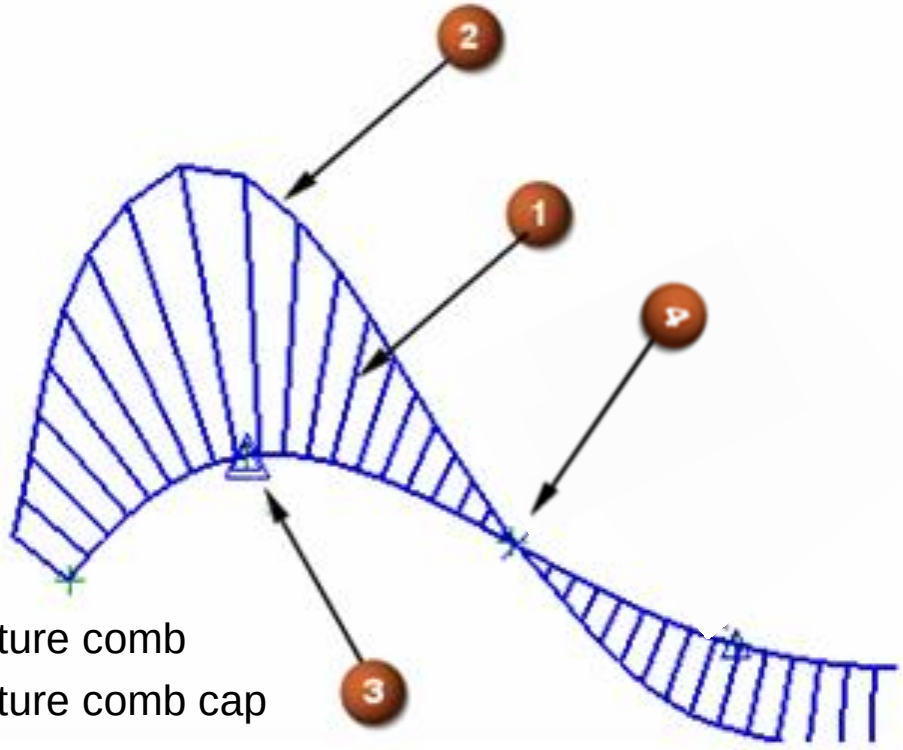
- Curvature is a degree to which a curve deviates from a straight line.
- The characteristics of curves can be analysed by the curvature plots.
- Curvature comb is a visual representation of a curvature plot and it can give you valuable information on the look and 'feel' of the curve.
- A curve is fair when the curvature plot changes smoothly.
- Inflection points occur when a curvature plot crosses the curve (sign change) - flat regions produce zero curvature value.

1. Curvature comb
2. Curvature comb cap
3. Peak
4. Inflection



Curve/Spline Analysis using Curvature Plots

- The curvature plot consists of segments normal to the curve emerging from a number of points on the curve and whose lengths are proportional to the magnitude of curvature at the associated point.



1. Curvature comb
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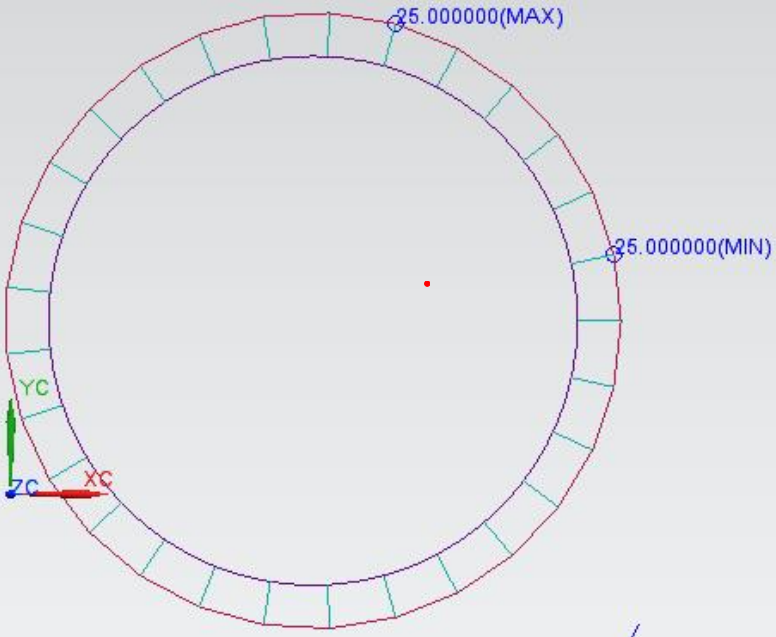
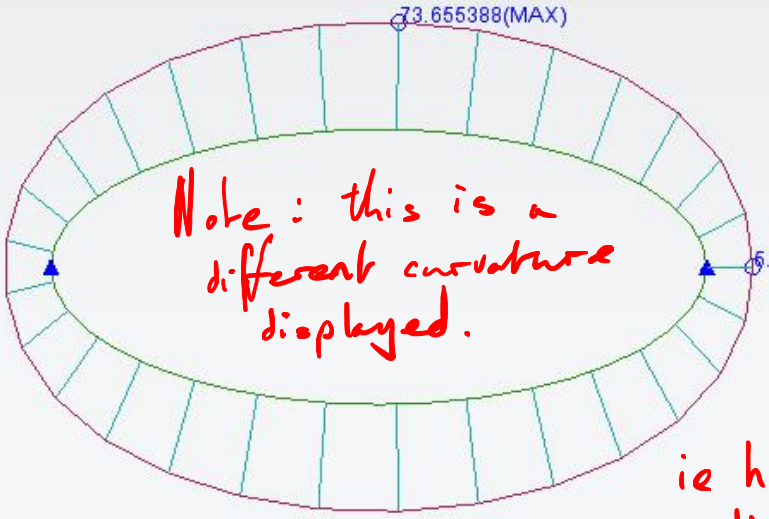
Examples of the curvature comb plots between two curves

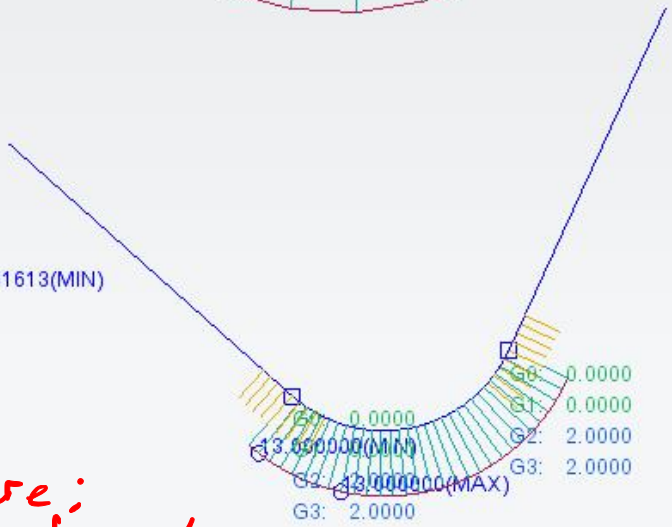
A line with no curvature

A circle or arc with constant curvature



An ellipse with curvature that varies between two max/min values

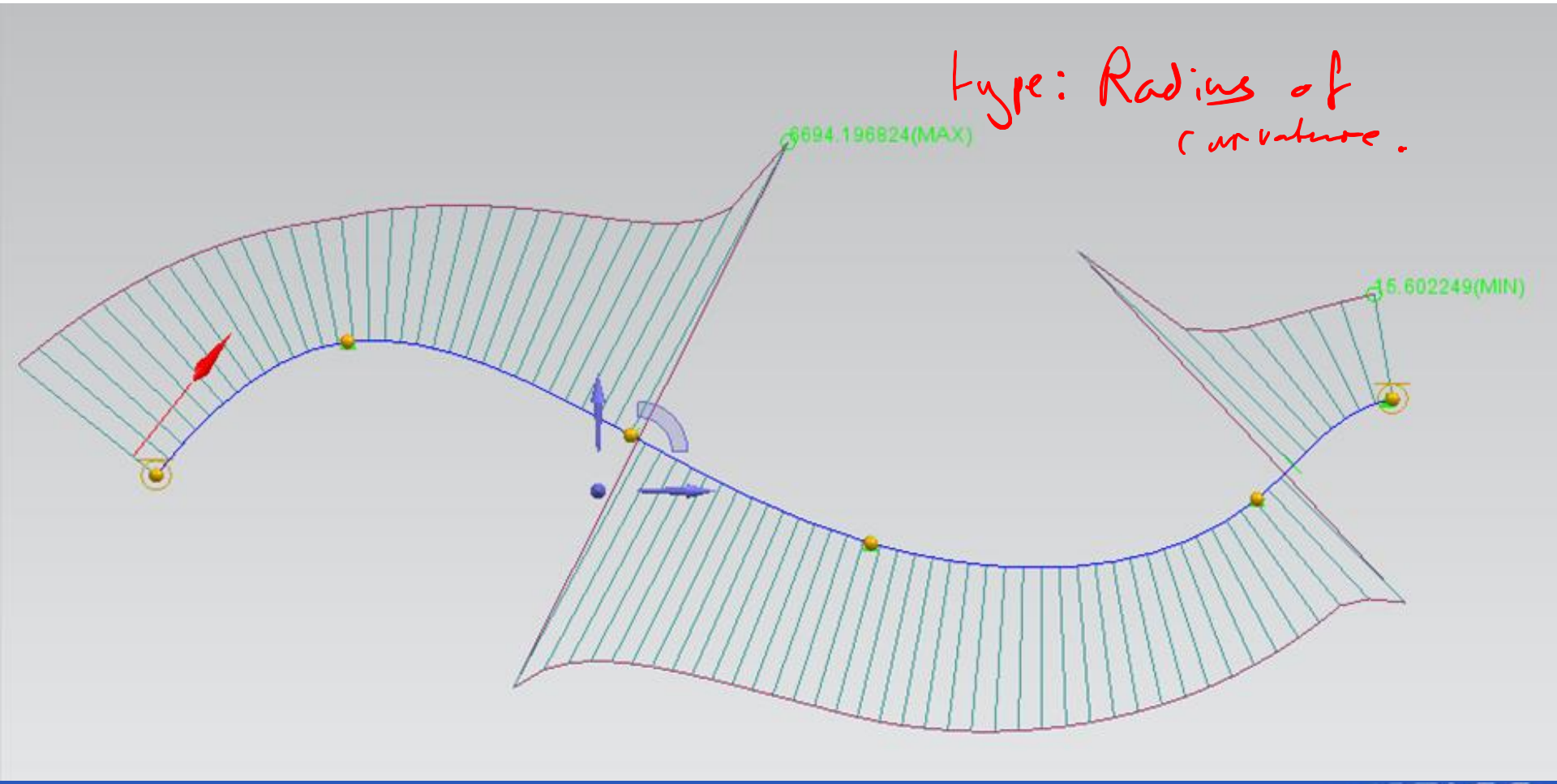




ie here; radius of curvature, not the rate of change of direction.

Example of the curvature comb plots between curves

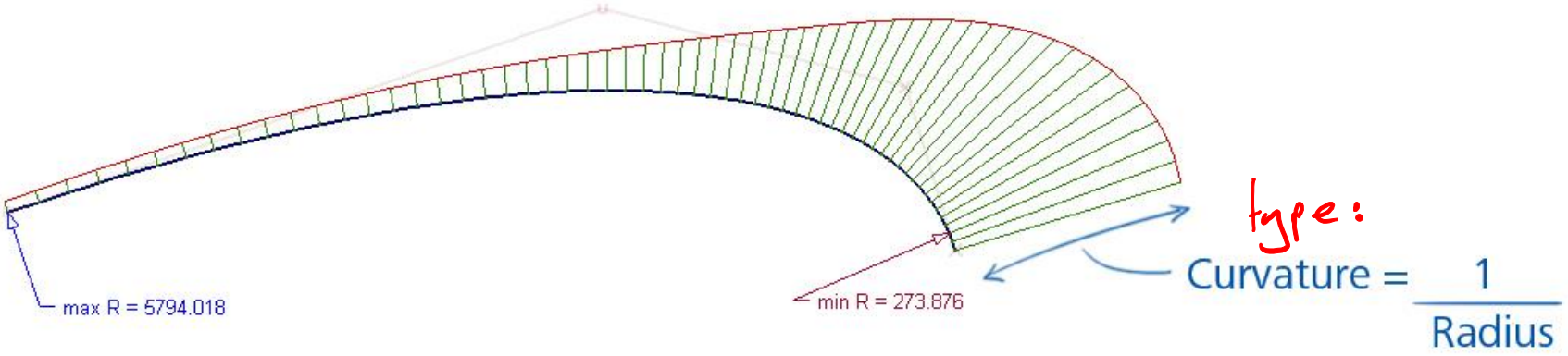
- A composite curve can have a variable curvature that changes and can flip convexity from one side to the other.



Interpretation of Curvature Combs

Curvature Comb Calculation

The 'Curvature' is calculated as the inverse of the radius at any one point. This calculation is displayed graphically at discreet points along the curve, and it is the way in which these curvature 'combs' change along the curve – the *flow* – that informs us about the shape:



The **length** of each curvature line is proportional to the inverse of the radius of the curve at that point.

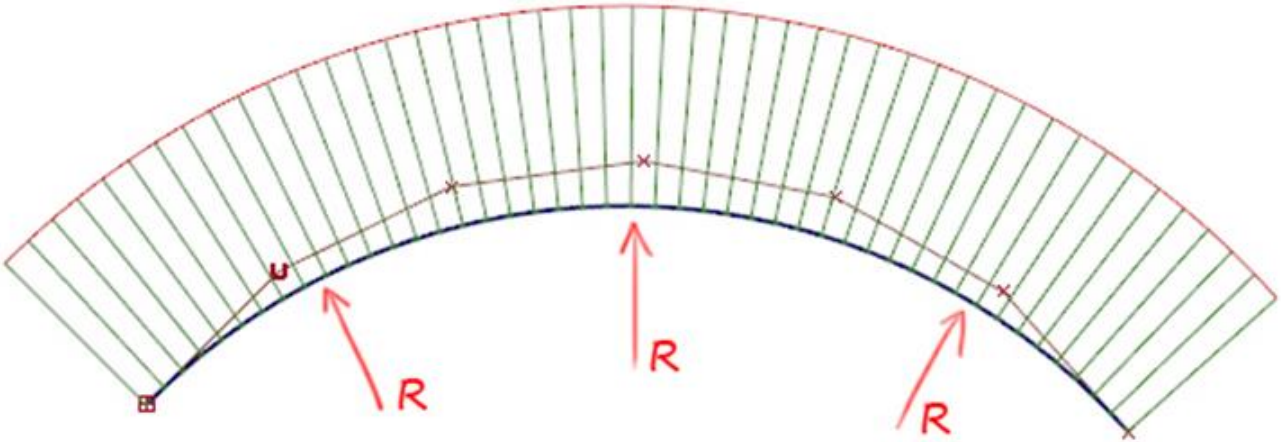
The **direction** of each curvature line is at 90 degrees (normal) to the curve at each point.

The **red** outline shows the smoothness and character of the curve

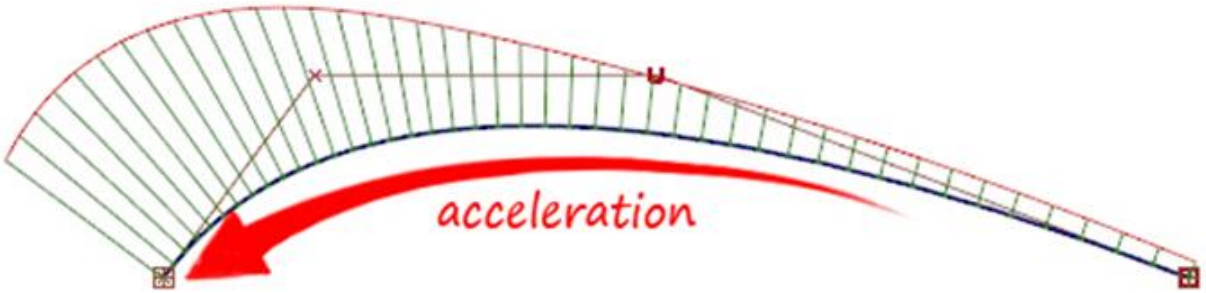
https://knowledge.autodesk.com/support/alias-products/getting-started/caas/CloudHelp/cloudhelp/2016/ENU/Alias-Tutorials/files/GUID-882B194B-E044-4921-B130-47391EFA1443-htm.html

Understanding the 'Flow' of the Curvature Comb

A constant length of comb means a constant curvature - in this case an arc.



A changing comb length shows an acceleration of curvature.



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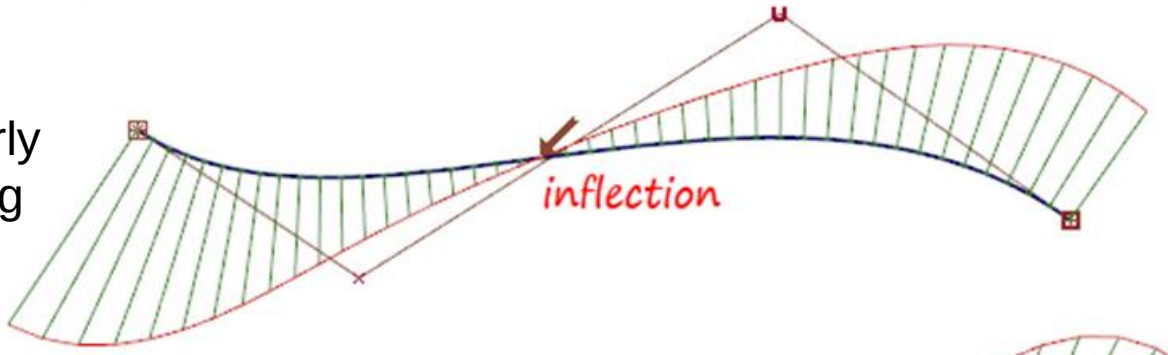
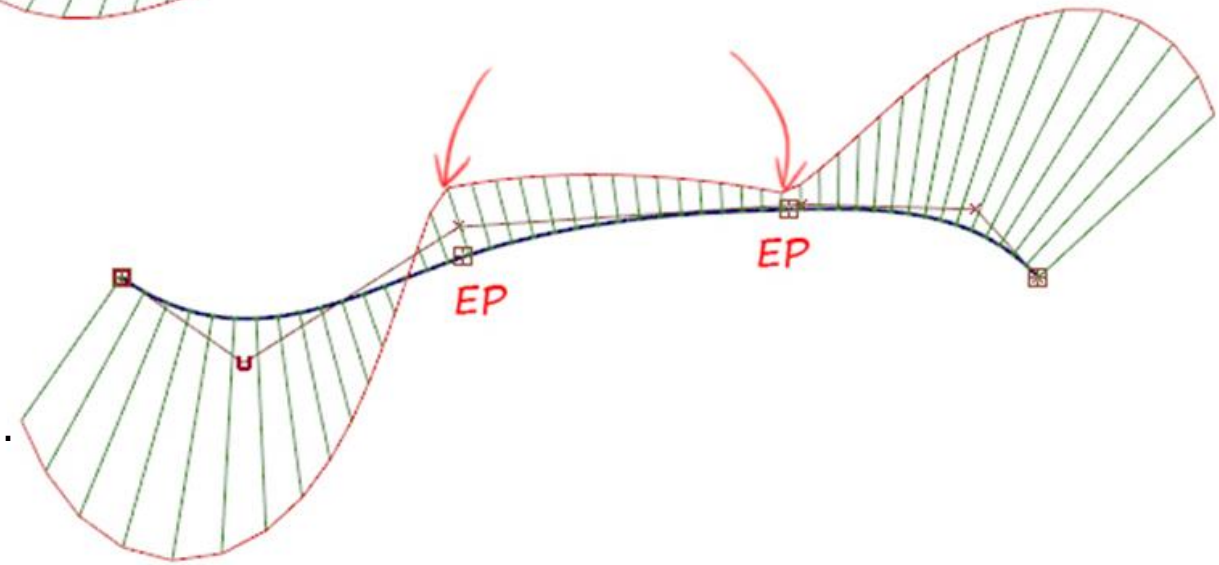
Understanding the 'Flow' of the Curvature Comb

Inflection point is shown clearly by the curvature plot switching sides.



Breaks in the red boundary curve shows curvature discrepancies at Edit Points (EP), or between two curves.



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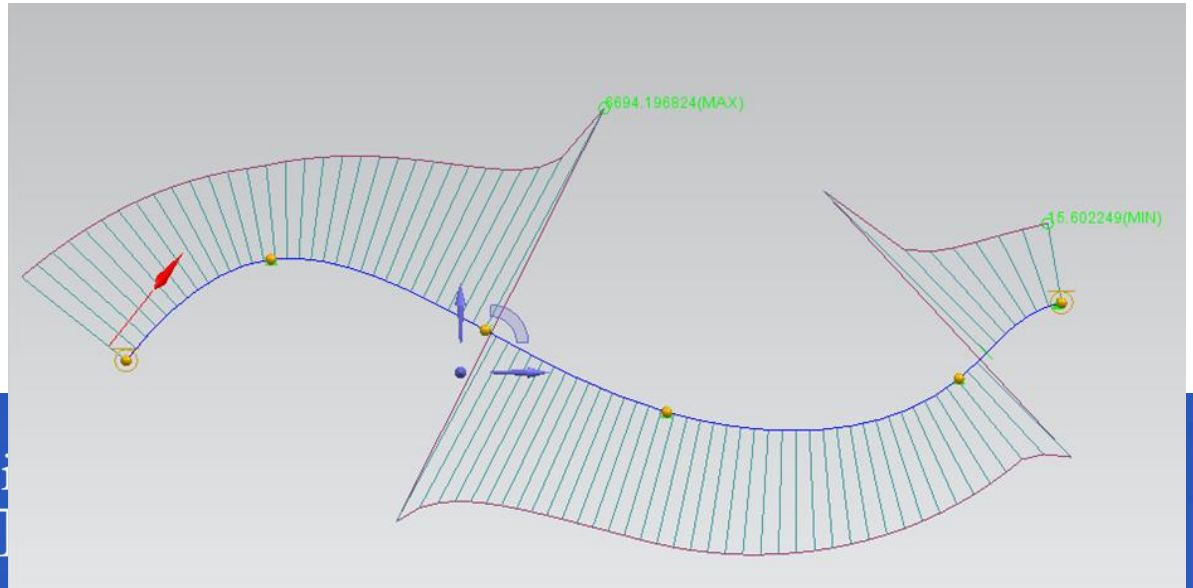
Composite Curve and Parametric or Geometric Continuity

- Engineering curves require continuity when a complex/composite curve is modelled by several curve segments pieced together end to end.

- Curve continuity is a measure of the “smoothness of the transition” between two curve segments.
- There are three types: position, tangent or curvature continuity.



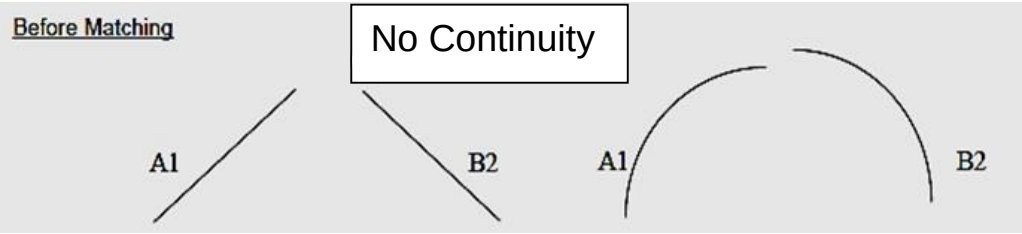
Types of Curve Continuity

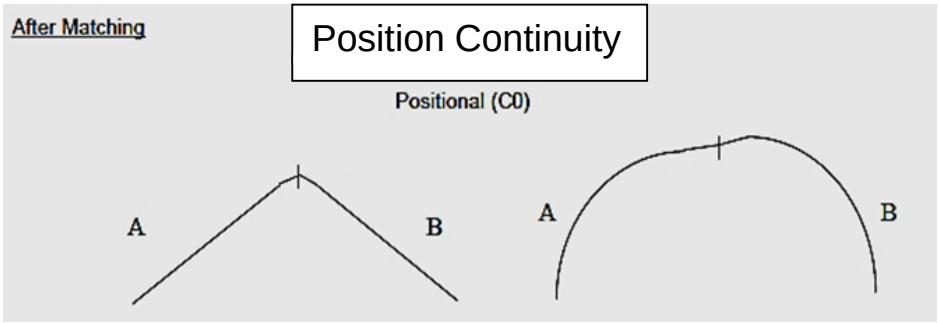
When curves do not meet.

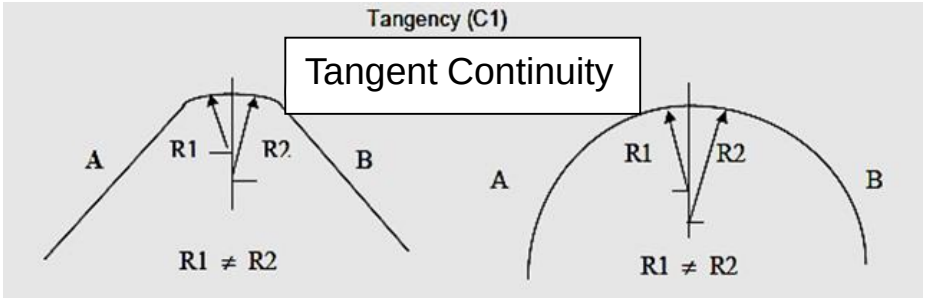
Zero-order (C^0); when curves meet.

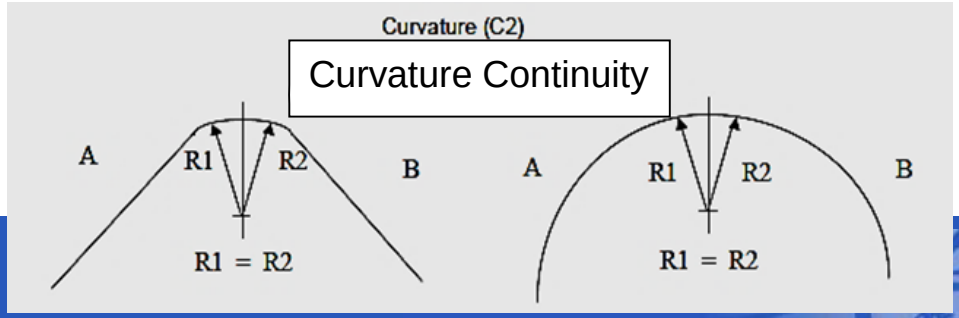
First-order (C^1); when curves meet and their tangents/slopes are shared.

Second-order (C^2); when the curvature, or tangent differential, is the same before and after.





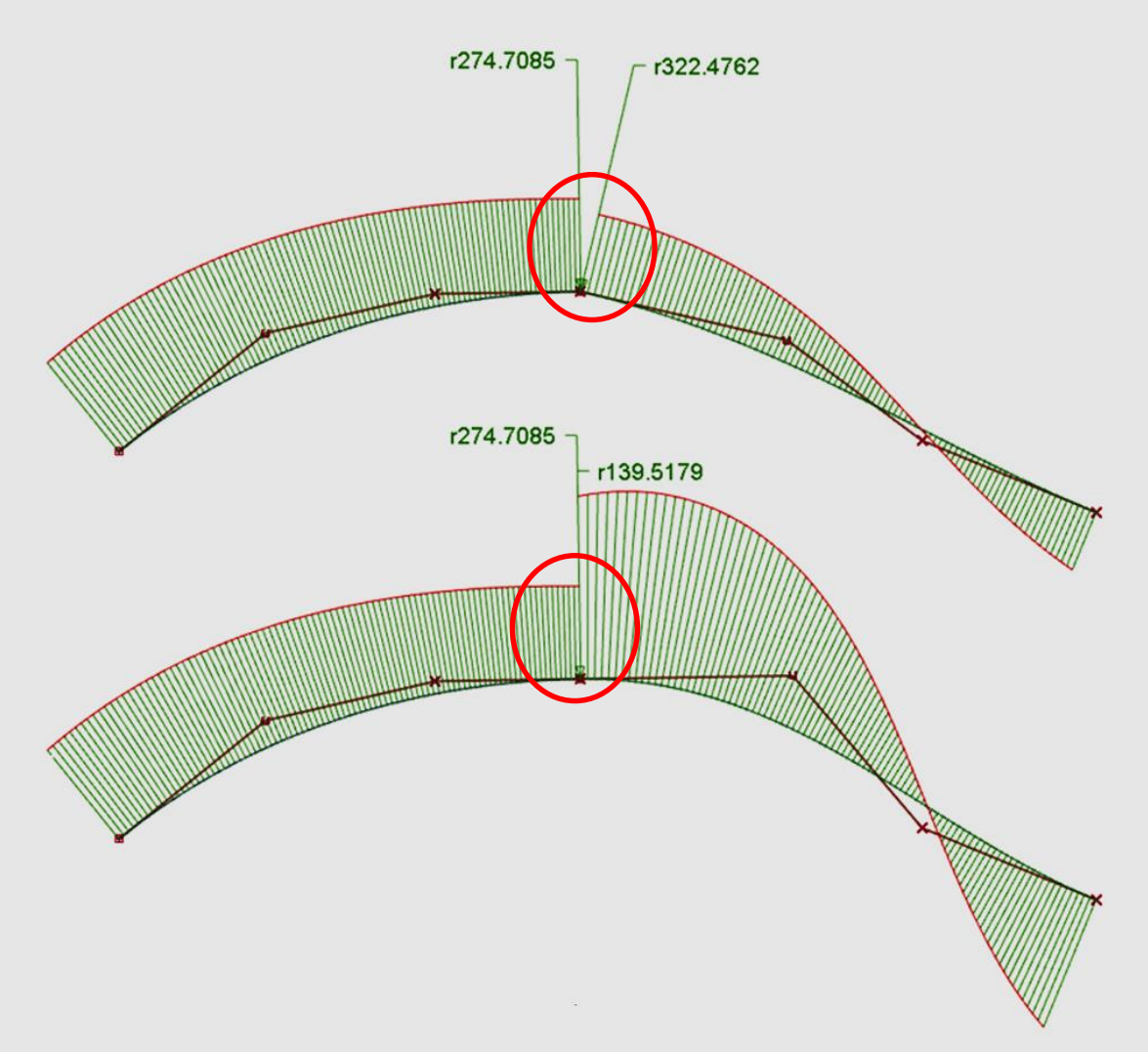




Curve Continuity Types with Curvature Comb Plots

G0 – Position

Curvature plots are at an angle



G1 – Tangent

Curvature plots are aligned but the radius values (i.e. 139 & 274) are different at the join.

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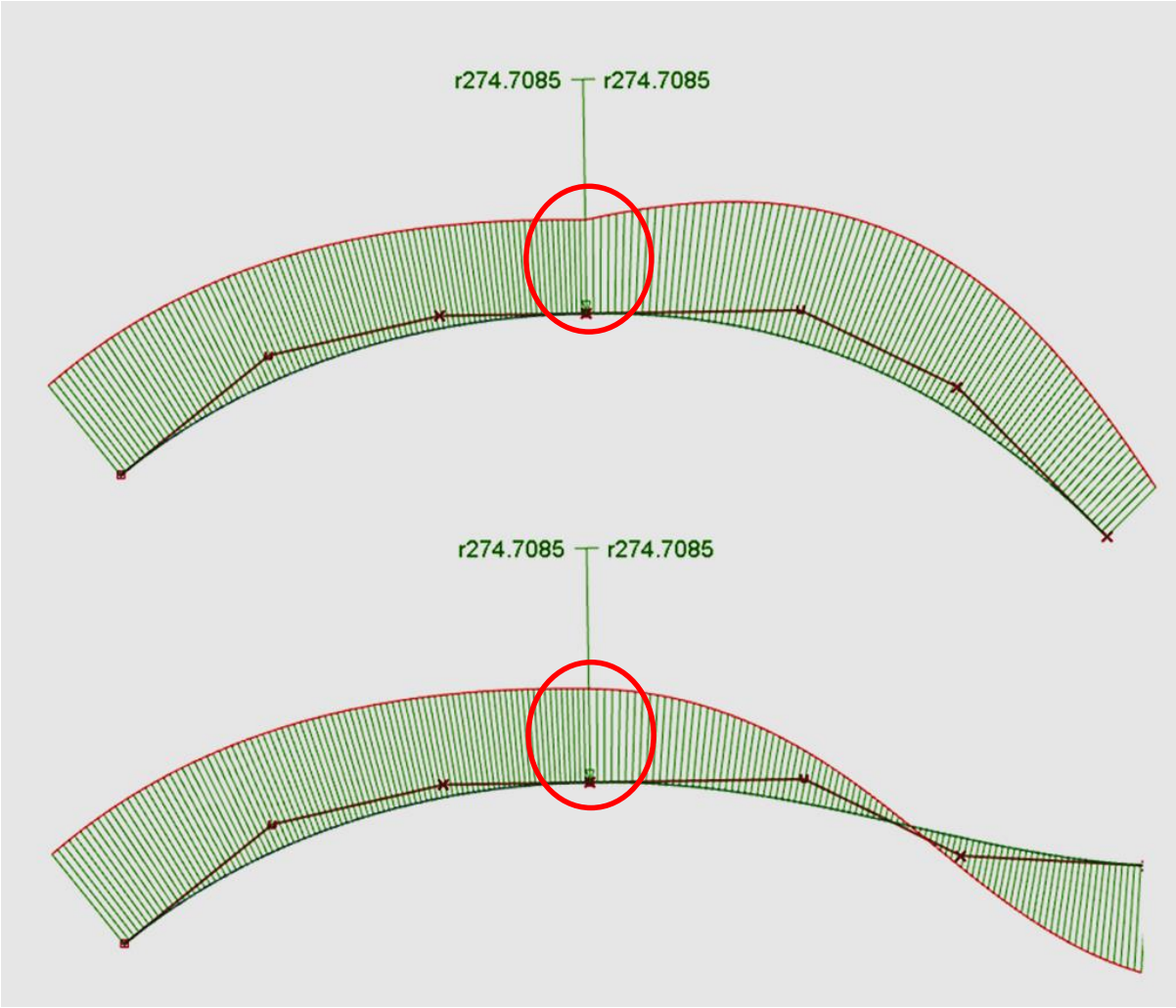
Curve Continuity Types with Curvature Comb Plots

G2 – Curvature

Curvature plots are aligned and the radius values are the same (i.e. 274) at the join.



G3 – Curvature

Curvature plots are aligned and the radius values are the same (i.e. 274) at the join.

The curvature plot outlines (red line) are tangential.

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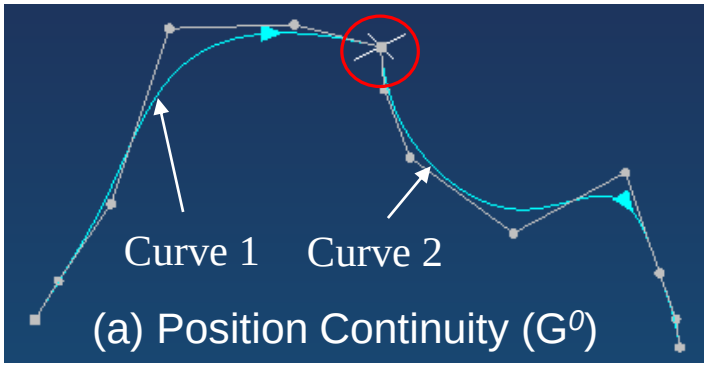
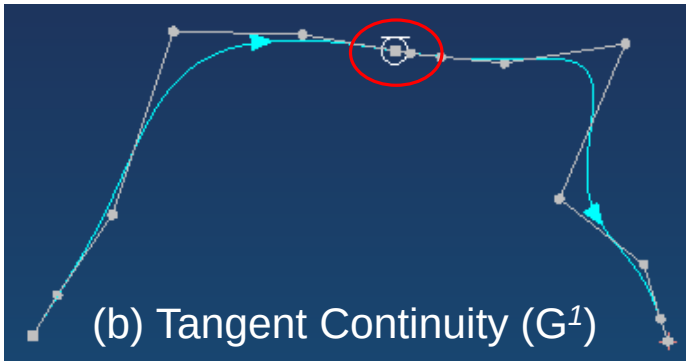
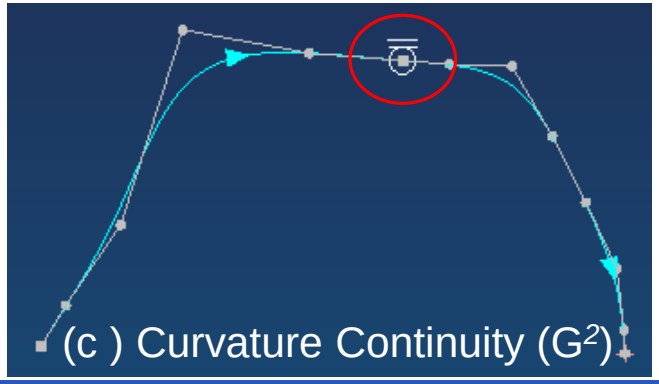
Examples of Curve Continuity

- Example below shows how the curve shape changes when continuity changes.





Note: In CAD, C is replaced with G and it is called the Geometrical constraint.



Example of Smooth/fair Curve

Part of the 'Beautification' cycle.

Fig. a) this curve cannot be considered as a fair curve because it has many sharp changes which created unnecessary inflection points.

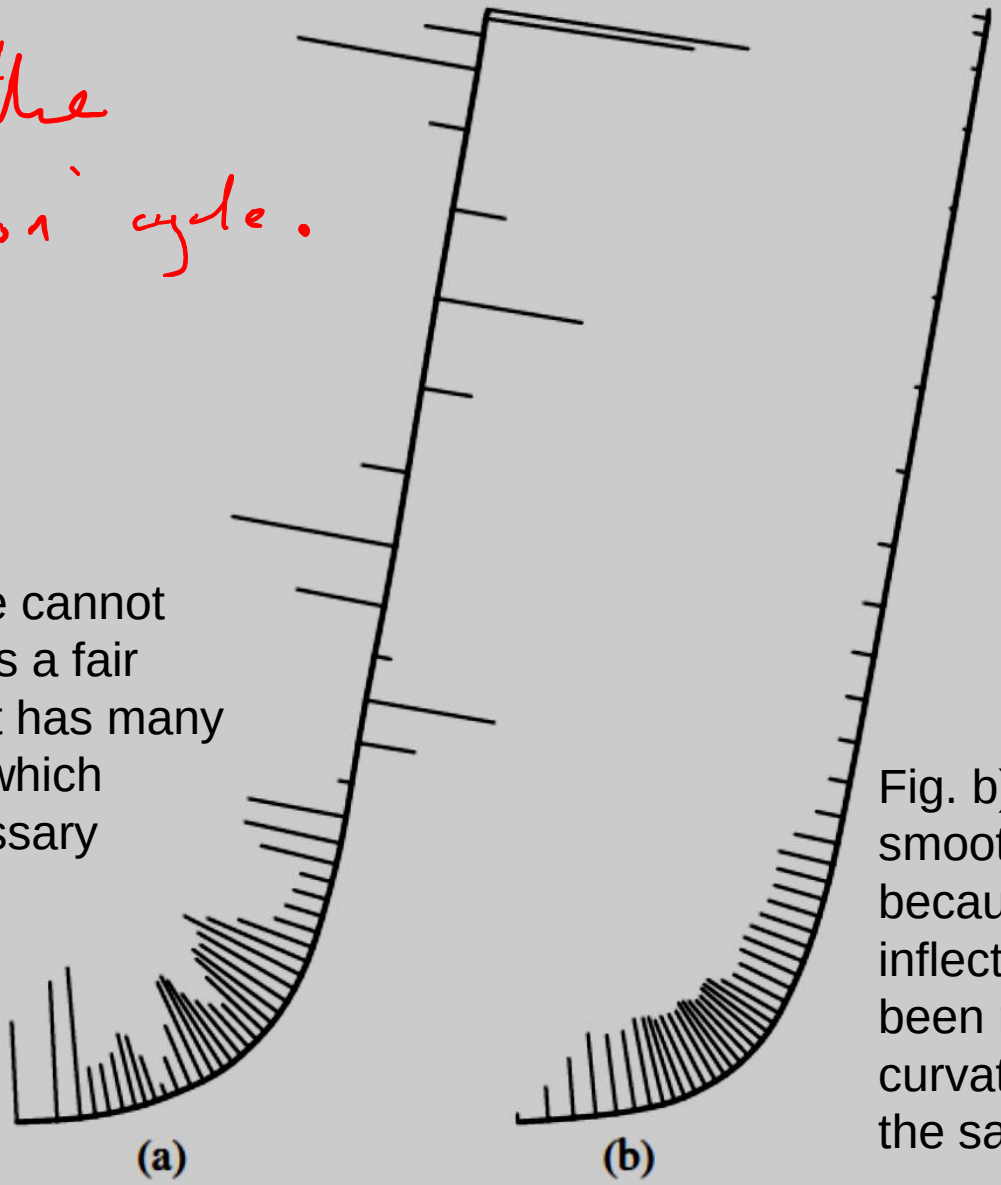
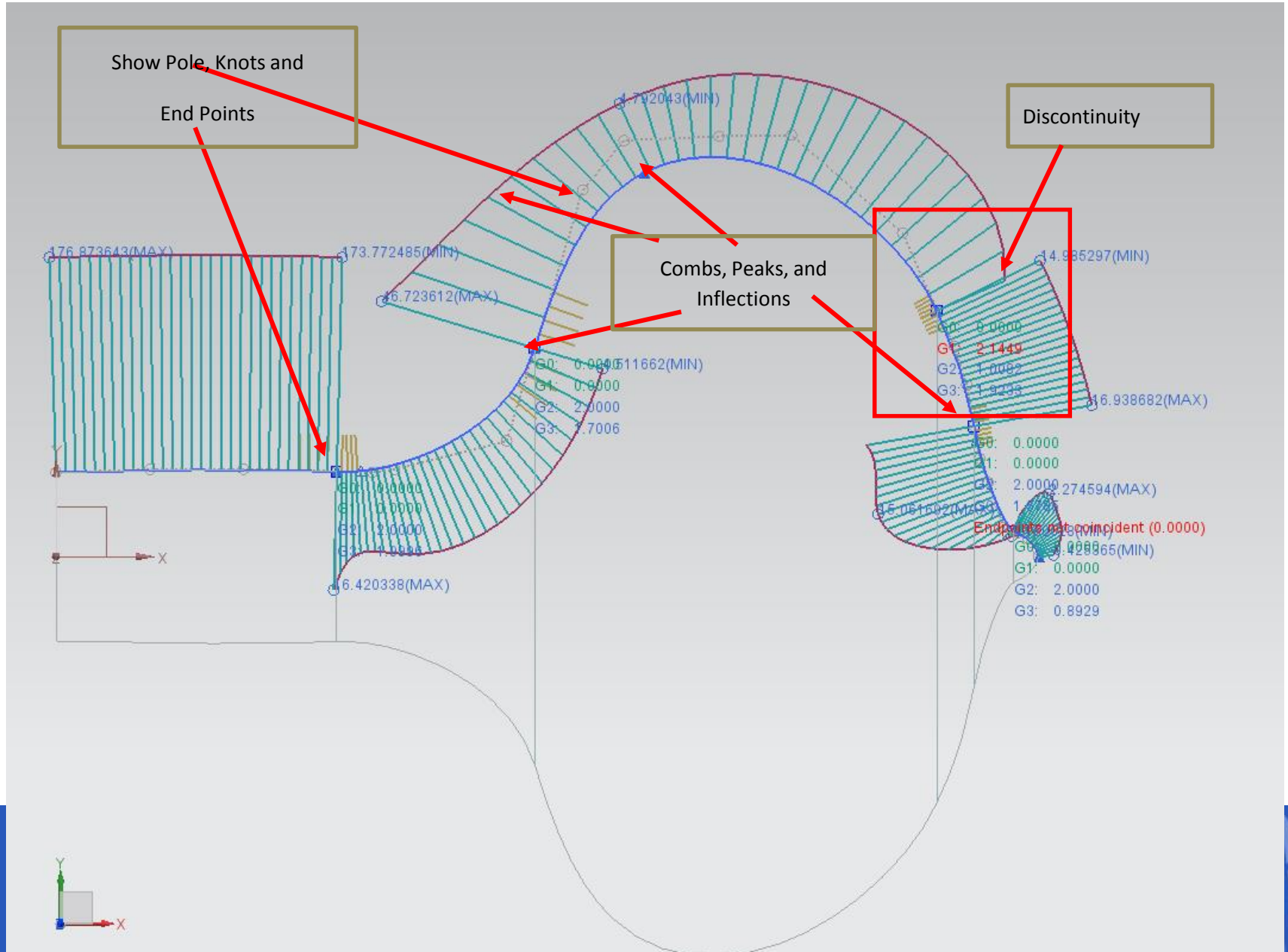


Fig. b) this curve is a smooth/fair curve because unnecessary inflection points have been removed and all the curvature combs point in the same direction.

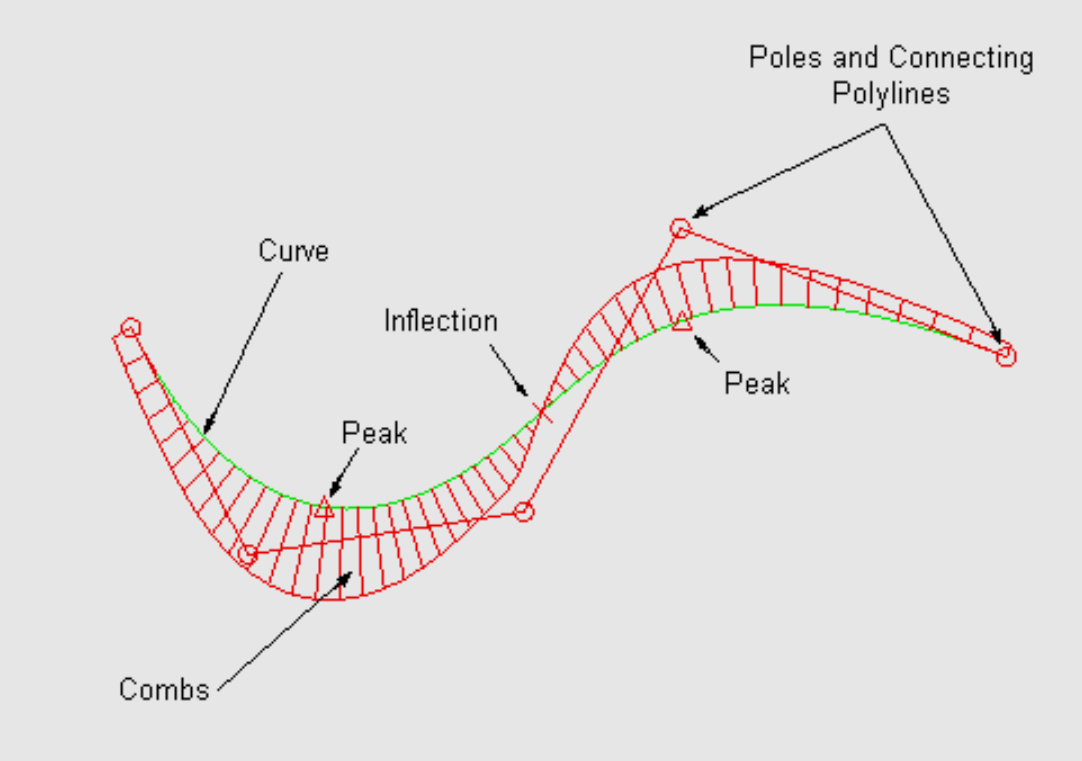
http://www.sciencedirect.com/science/article/pii/S0029801806000163

Fig. 2. Typical curve fairing problem: (a) initial curve and (b) fairing-optimized curve.

Example of Curvature Plots Information



Curve Analysis Presentation



Any questions?