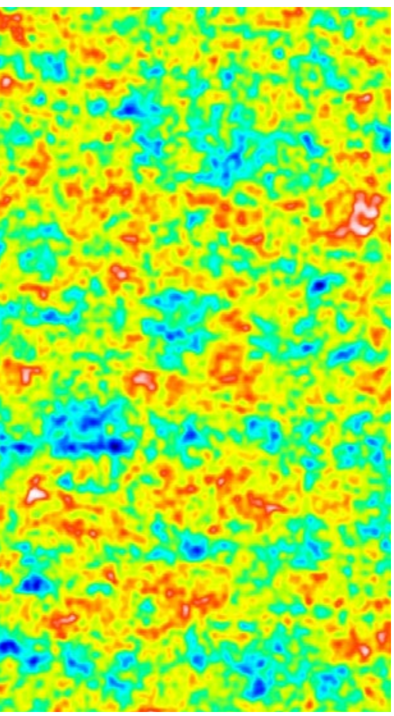
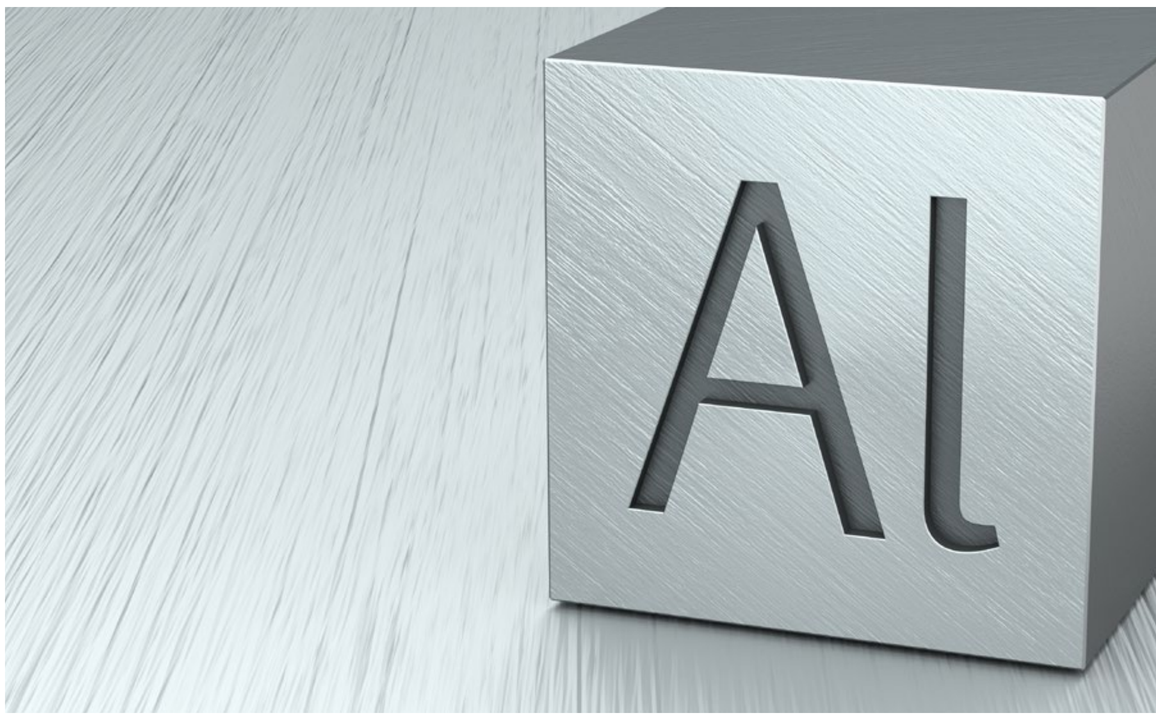
Polytec





Characterization of aluminum alloy sheets

Methods to determine the roping grade

Application note

In automotive applications, customers do not accept roping structures on painted, visible parts. Therefore, the roping grade for a visible part must be specified carefully.

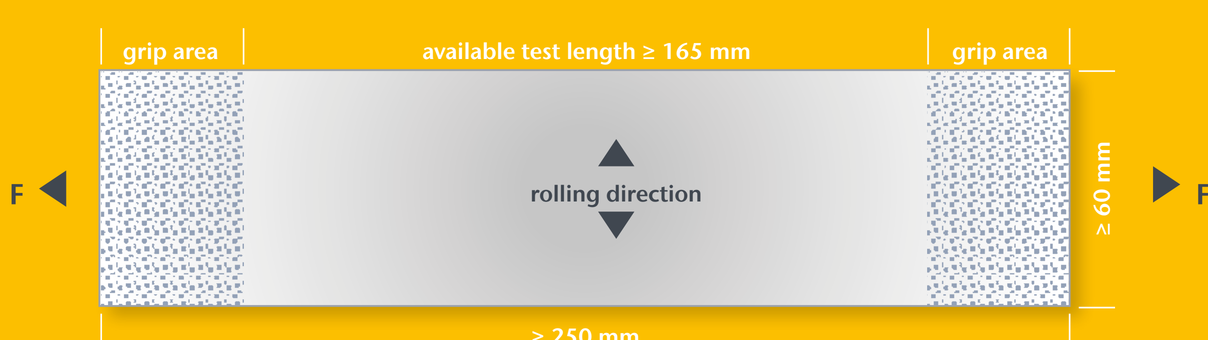
The origins of roping

Besides other advantages, aluminum alloys permit lightweight structural designs and innovative solutions to weight reduction in automotive applications. Consequently, the demand for aluminum alloys is growing rapidly for applications where strength-to-weight ratios are critical. Aluminum producers supply the market with unfinished aluminum alloys that must be rolled, stretched, and pressed into the appropriate shape. As a result of forming operations, the grain structure of the alloys is re-ordered, leading to an increase in surface roughness and an "orange peel" appearance. Under certain conditions, the surface roughness can consolidate into larger banded or "roping" structures that appear parallel to the rolling direction and perpendicular to the stretching direction. Typically, the structure widths are between 0.2 to 2 mm, and the lengths are between 10 to 30 mm. The roping structures can be identified visually and destroy the appearance of the surface.

In contrast to the "orange peel" surface texture, the roping structures are visible even after painting. In automotive applications, customers do not accept roping structures on painted, visible parts. Therefore, the roping grade for a visible part must be specified carefully. Since the appearance of roping structures depends on the alloy composition and the thermo-mechanical manufacturing conditions, a consistent roping characterization procedure is needed for developing new alloys and for quality control of manufactured products. Any roping characterization procedure requires that a quantitative grade must be defined first before it can be measured. In production, an aluminum sheet is stretched or strained perpendicular to the rolling direction by 5-20 %, as shown in figure 1 (VDA-Recommendation 239-400).

In the past, surfaces were inspected visually. Predictably, the results were inconsistent and depended strongly on each observer's experience and the sample's preparation and illumination. Often the results were not repeatable, and a precise characterization was almost impossible. Surface measurement (areal topography or a series of line profiles) provides a method for reliably and objectively grading the roping structures.

In the following text, two different methods of roping grade measurement that use advanced optical surface metrology are discussed.



1
Sample dimensions, location of the sample to rolling direction and direction of pre-strain

Method 1

Determination of the roping grade using the S_a parameter

After rolling and stretching an aluminum alloy sheet, the roughness of the surface is often increased, and roping structures appear. The areal S-texture parameters (i.e., S_a, S_q) according to standards ISO 25178-2 and 25178-3 can be used to characterize this new surface roughness. Hotz et al. [1] published their characterization results using the S_a parameter. The S_a parameter describes the average deviation from the least square level and corresponds with the R_a, W_a or P_a parameter for line characterization. In general, the S-texture parameters are defined for scale-limited surfaces. However, the ISO 25178-700 standard does allow application-oriented scale limitations for the calculation of the S-texture parameters.

Since roping structures have widths of several millimeters, the S_a parameter can be calculated over scale-limited structure sizes. For example, Hotz et al. investigated surfaces using the S_a(1-15) [2] parameter where structures longer than 15 mm and grains smaller than 1 mm were filtered out by a Gaussian high-pass filter with the Nesting index (cut-off) of 1mm or low pass filters with the Nesting index (cut-off) of 15 mm. As shown in figure 2, the roping classes are defined by the S_a value for stretched aluminum alloy sheets. Class 4, for instance, represents the strongest roping (largest S_a) with smaller classes indicating much less roping (smaller S_a).

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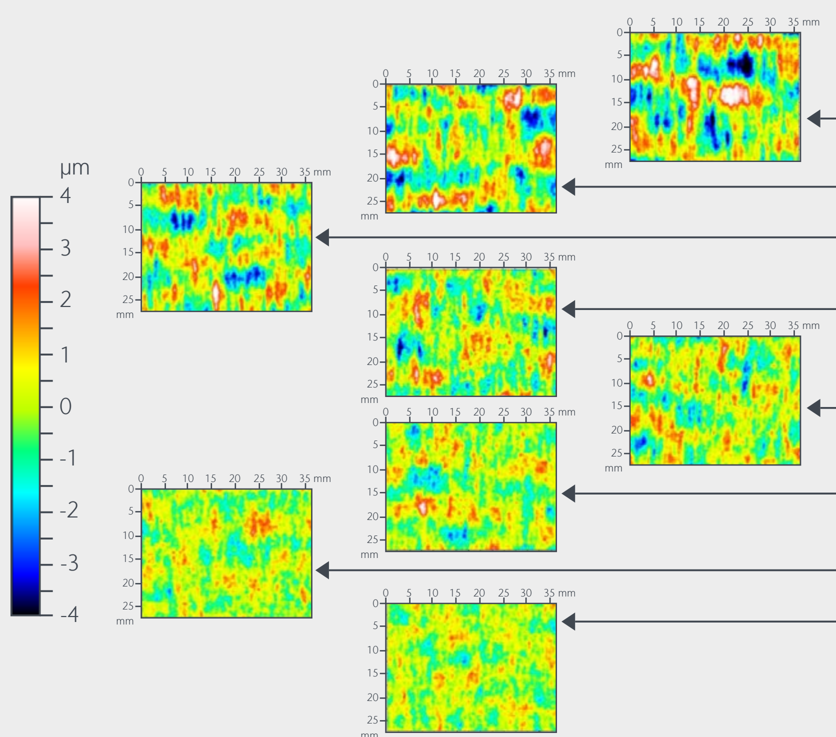
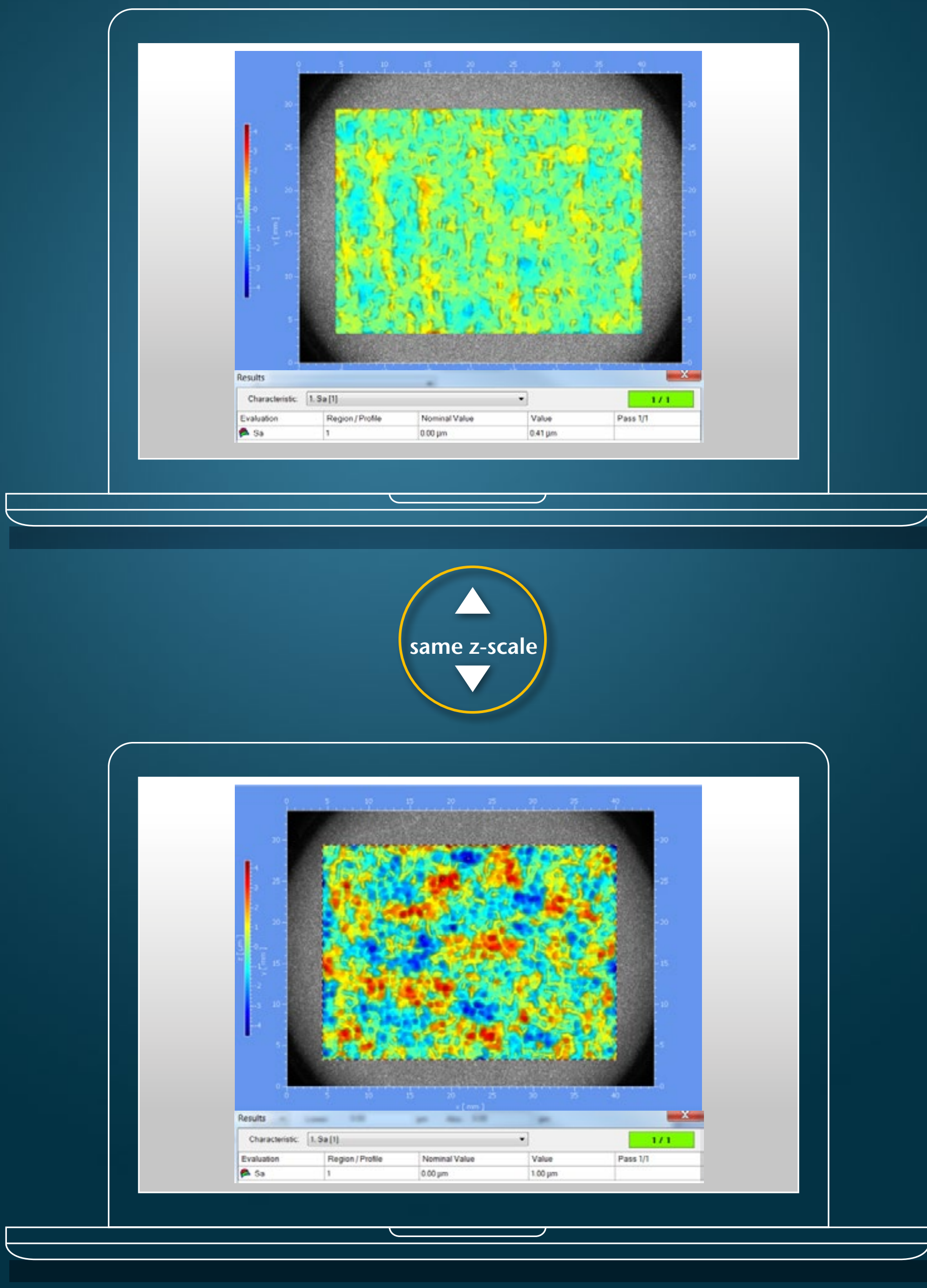
Roping classes are defined by the S_a parameter according to Hotz et al. (Recken: rolled)



10% stretch, lateral S_a [mm]	
Class 4.0	> 1.1
Class 3.5	1.1
Class 3.0	1.0
Class 2.5	0.9
Class 2.0	0.8
Class 1.5	0.7
Class 1.0	0.6
Class 0.5	0.5

A practical example is shown in figure 3 ▶

[1] W. Hotz, R. Müller, J. Timm, "Ropingmessung an Aluminium-Automobilaussenhautblech", Tagungsband Werkstoffprüfung 2009: Fortschritte der Kennwertermittlung für Forschung und Praxis, eds. M. Borsutzki, S. Geisler, Stahleisen Verlag, Düsseldorf (2009) 365–370.
[2] Standard notation for measuring the S_a parameter using these filters.



3
Two topographies with different roping grades. At the top: Roping grade of 0.41 belongs to class 0.5; at the bottom: Roping grade of 1.0 belongs to class 3.0

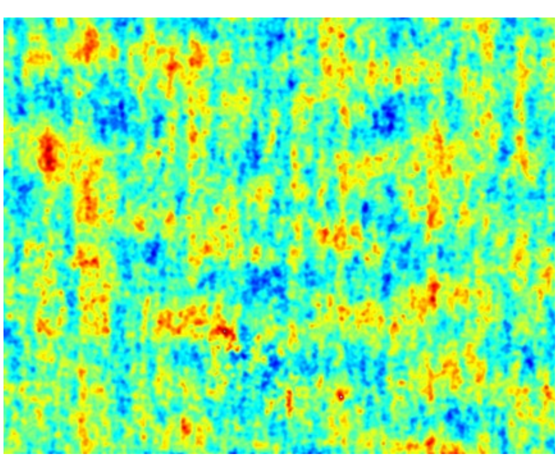
Method 2

Using imprints to determine the roping grade

As a second approach to determine the roping grade, the German Association of the Automotive Industry (GAAI) recommendation VDA 239-400, which uses an imprint of the surface, can be applied. The imprint method has many similarities to making a copy of a credit card with raised font structures by placing a paper over the structures and rubbing with a pencil to make the raised font surfaces visible: the deep areas remain bright, and the high ones are darkened. Using specially prepared adhesive tape, an imprint is taken and scanned at 300 dpi to form a gray image. At this resolution, the small structures (roughness) that are not relevant are filtered out and are no longer recognizable. The grayscale values are indicators of the heights when the imprint process is done correctly. The gray image is evaluated by software, which calculates the roping degree based on the standard from 0 (no roping) to 9 (very strong roping). While this approach seems simple, it is labor-intensive, time-consuming, lacks precision and error-prone. These disadvantages are eliminated when using TopMap white-light interferometers from Polytec.

White-light interferometry improves the determination of roping grades

Polytec provides optical measurement technology using large-scale scanning white-light interferometers as an industry-accepted alternative to the imprint method. These optical systems are fast and record the topography of the aluminum surface in a few seconds. As a companion to the system, Polytec provides a software module that maps the 3D result into a repeatable grayscale image that replaces the handmade imprints. To ensure that the results are comparable to the GAAI standard, Polytec developed an algorithm that prepares and exports the data for further processing to determine the roping grade. In addition, the Polytec software calculates the RK parameter according to the VDA 239-400 GAAI standard and the W_{sa} (1-5) as well as the W_a (0,8) parameter according to the Steel Institute VDEh guideline SEP 1941. The line profile parameter W_{sa} (1-5) is useful for both aluminum and steel industry applications and describes a “window-waviness” with a scale limitation between 1 and 5 mm.



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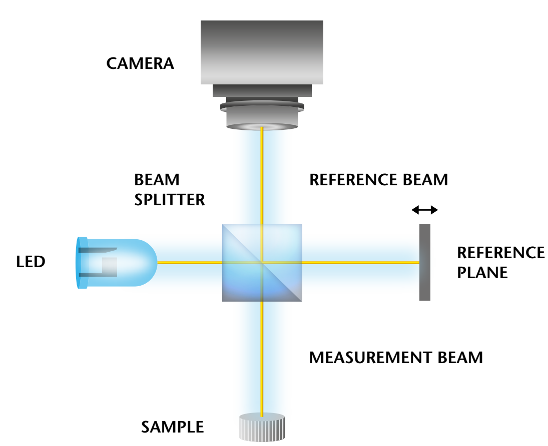
Topography measured with a Polytec interferometer

Aluminium surface
W_{sa}(1-5): 0.81 µm, W_a 08: 1.23 µm
Roping grade: 3.41



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Principle of the white-light interferometry

Polytec's innovation eliminates the manual imprinting process while determining the roping grade much faster and more accurately. Properly installed, the Polytec equipment can automate the entire measurement process, giving higher accuracy, better consistency, and higher throughput simply because the surface data is captured without contact using white-light interferometry. These automated measurements help less experienced production operators produce well-documented "metrology" lab results.

A significant advantage of using a white-light interferometer is that the resolution in the vertical direction is independent of the measuring field size. In fact, the ideal instrument for determining the roping grade is a white-light interferometer with a telecentric beam path.

This optical design advantage allows the characterization of relatively large surface areas in a single measurement. More importantly for some surfaces, accurate and reproducible results can be obtained from surfaces with high-intensity variations, allowing a more detailed roping grade classification.

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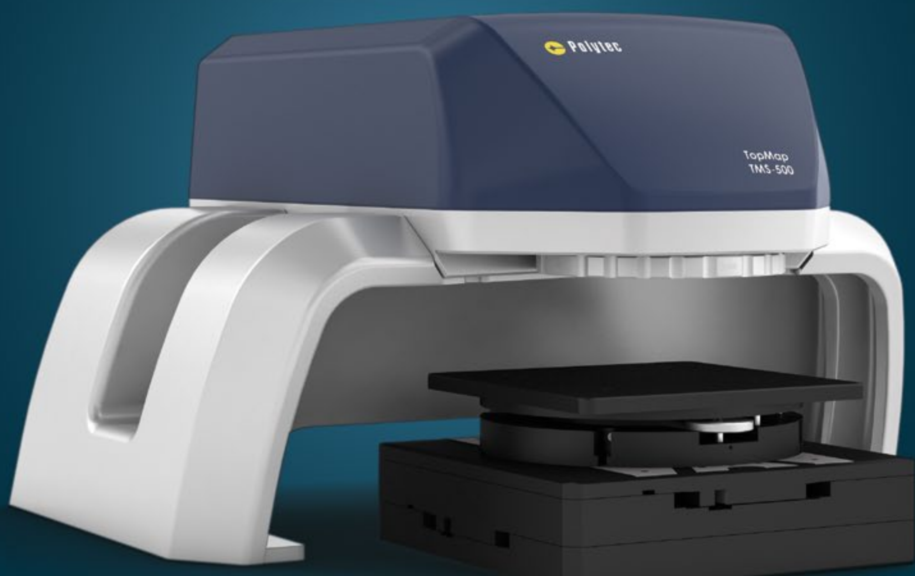
Conclusion

Polytec's TopMap Pro.Surf system is the optimal choice for determining roping grades for industrial quality control and assurance. With large-scale surface area characterization that is done quickly, accurately, and efficiently in a single measurement, TopMap white-light interferometers are an essential tool for production engineers concerned with roping grades for QC and QA processes as well as for R&D engineers developing new alloy compositions.



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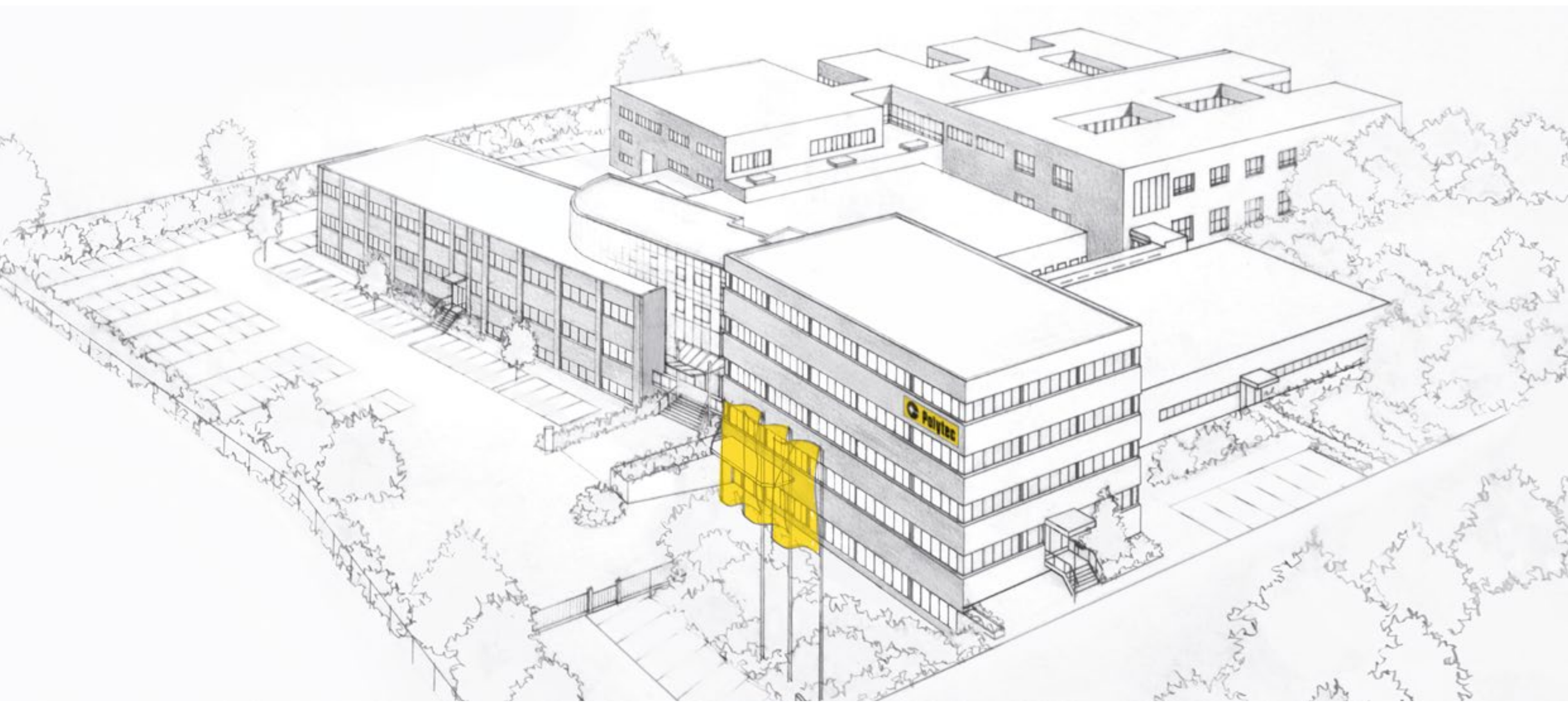

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