Structured sheet metal

Part I: Comparing processes

Editor's Note: This article is Part I of a two-part series discussing structured sheet metal and different structuring processes. Part II, which will appear in the June issue, will discuss specific applications for and advantages of Vault-structured™ sheet.

This column was prepared by Michael Mirtsch and Ajay Yadav of the Engineering Research Center for Net Shape Manufacturing (ERC/NSM), The Ohio State University, Taylan Altan, professor and director.

In aircraft and automotive production, there is significant demand for lightweight construction using sheet metal components. Increasing sheet metal component rigidity while reducing weight can be achieved by substituting steel with aluminum, magnesium, or titanium alloys; advanced high-strength steel (AHSS); or 3-D structured sheet metal.

Structured sheet is thin sheet metal with a 3-D structure. The 3-D structure enhances the mechanical properties of components, primarily by increasing bending stiffness because of increased inertia (the higher the structure, the stiffer the sheet). Strain hardening, which occurs during the structuring process, also improves the rigidity of the product. Well-known structured sheet applications include corrugated sheets for roofs and facades. Initially 3-D structured sheet was used for producing products that required increased rigidity; however, these materials now are used in a wider range of products.

Automotive Applications

Consumers and the government are demanding fuel-efficient vehicles to meet higher safety and environmental standards. Figure 1 shows a structured rear panel on a 2004 Mercedes SLK®. This panel adds stiffness and improves the car's acoustic behavior by dampening noise from the trunk and rear of the automobile, which can enter the passenger compartment.

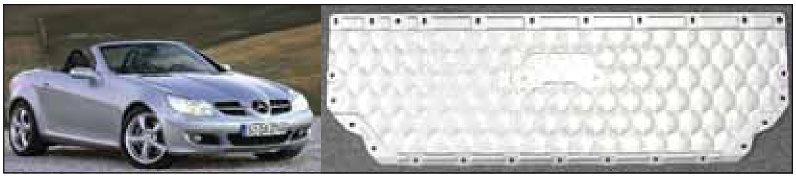


Figure 1

This rear panel on a Mercedes SLK® was produced from Vault-structured sheet with a hexagonal staggered pattern. This structuring improves the sheet's rigidity as well as its noise-dampening properties.
Source: F. Mirtsch, "Bionic-Method of Efficient Light-Weight Production," in proceedings from Global Conference Sustainable Products, 9/29/ 2004 -10/1/2004, p. 97.

Structured sheet also can be used in thermal engineered products. In heat exchangers, for example, increased fluid turbulence along 3-D structured surfaces, combined with a larger surface area, significantly improves the rate of heat transfer. Other applications for structured sheet include building construction and architectural products (ceilings, walls, and door panels) and packaging (cans, containers, and bottles).

Structured Sheet Metal Processes

Structured steel and aluminum-alloy sheet metal mainly are produced by rolling (rolled structured sheets), embossing (waffle-type structured sheets), or hydroforming (spherical-type structured sheets), as shown in Figure 2. These processes create high strain hardening but require larger forming pressures. The Vault-structuring method (Figure 1 shows a hexagonal Vault Structure) is a new technology that produces structured sheets at lower forming pressures. Strain hardening in Vault Structuring is reduced, which allows for better formability during secondary processes. Examples of sheets manufactured with these processes are shown in Figure 3, as well as achievable structure heights and the pressures required to form them.

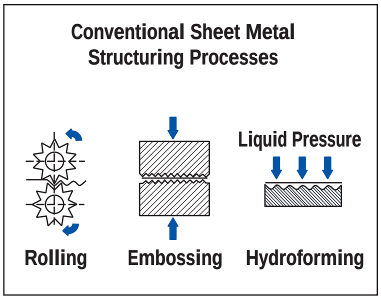


Figure 2

Structured steel and aluminum-alloy sheet metal mainly are produced by rolling (rolled structured sheets), embossing (waffle-type structured sheets), or hydroforming (spherical-type structured sheets).

Vault-structuring Process

The basic Vault-structuring process is shown in Figure 4. A thin-walled, cylindrically shaped sheet is supported internally with rings. After an external hydrostatic or elastomeric pressure is applied, the sheet deforms inward, and at a critical value of applied pressure, the sheet collapses into a rectangular staggered structure automatically. A rectangular die is not used in this process; the staggered structure is self-organized. The circular straight folds in the final part are positioned by the supporting rings. However, the axial folds (horizontal folds), which are staggered, not aligned, are

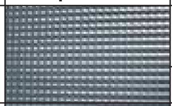
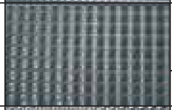
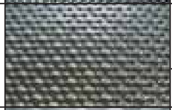
Manufacturing Process	Structure Specimen	Material (thickness = 0.5 mm)	Structure Height (mm)	Applied Pressure (N/mm^2)
Rolling		Aluminum Alloy (AA 5052-0)	2.15	3.69
		Deep-Draw Steel	1.8	3.32
Rolling		Aluminum Alloy (AA 5052-0)	2.4	6.16
		Deep-Draw Steel	—	—
Rolling		Aluminum Alloy (AA 5052-0)	1.6	3.46
		Deep-Draw Steel	1.6	5.39
Hydroforming		Aluminum Alloy (AA 5052-0)	1.6	3.46
		Deep-Draw Steel	1.4	4.46
Vault Structure		Aluminum Alloy (AA 5052-0)	3.1	0.23
		Deep-Draw Steel	3.1	0.23

Figure 3

Structure height and forming pressures are compared for aluminum alloy AA 5052-O and deep-draw steel produced by different structuring processes. The Vault-structuring method shows the capability to form relatively high structures at low forming pressures. Source: M. Hoppe, "Umformverhalten strukturierter Feinbleche," Diss. Bradenburgische Technische Universitat (BTU), Cottbus, Germany, 2003, p. 28, 46.

created automatically during the forming process, based on the principle of energy minimization.

In contrast to the conventional techniques, Vault Structuring is not done with highly sophisticated tools at high forming pressures (see Figure 3), but at low pressures and with very simple supporting tools (ring or helix). Based on this Vault-structuring principle, this method also can be used to form flat sheets with hexagonal or rectangular staggered structures.

Structured Sheet Properties

Structured sheet metal has increased bending stiffness. To evaluate this property, a three-point bending test can be used. As a result, a deflection-versus-bending-force curve is obtained, as shown in Figure 5. This test indicates that a Vault-structured sheet is three to five times stiffer than nonstructured sheet.

A similar comparison using the three-point bending test for flat sheet, rolled-structured, and Vault-structured high-strength steel (DP-K30/50) gives results similar to those in Figure 5. High-strength steels are difficult to form, and at times cannot be structured with conventional structuring techniques to give large structure depths. Using low forming pressures such as the Vault-structuring technique can structure even high-strength steel, aluminum alloys, and fiber materials like paper and cardboard.

Innovative and optimized structure designs, together with cost-effective structuring processes, are expected to increase the use of structured sheet metal components in the future. ST

Taylan Altan is a professor and director of the Engineering Research Center for Net Shape Manufacturing, 339 Baker Systems, 1971 Neil Ave., Columbus, OH 43210-1271, 614-292-9267, fax 614-292-7219, www.ercnsm.org. The ERC/NSM conducts research and development; educates students; and organizes workshops, tutorials, and conferences for the industry in stamping, tube hydroforming, forging, and machining.

Write 7 on reply card

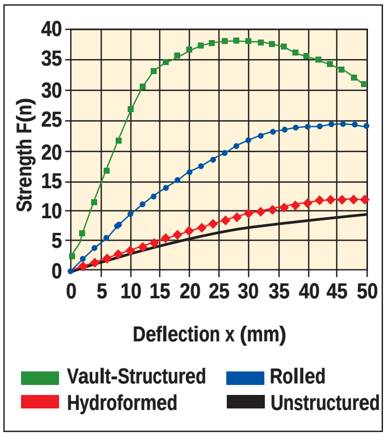


Figure 5

Bending stiffness for sheet produced by rolling, hydroforming, and Vault Structuring can be determined with a three-point bending test.
Source: F. Mirtsch, "Bionic-Method of Efficient Light-Weight Production."

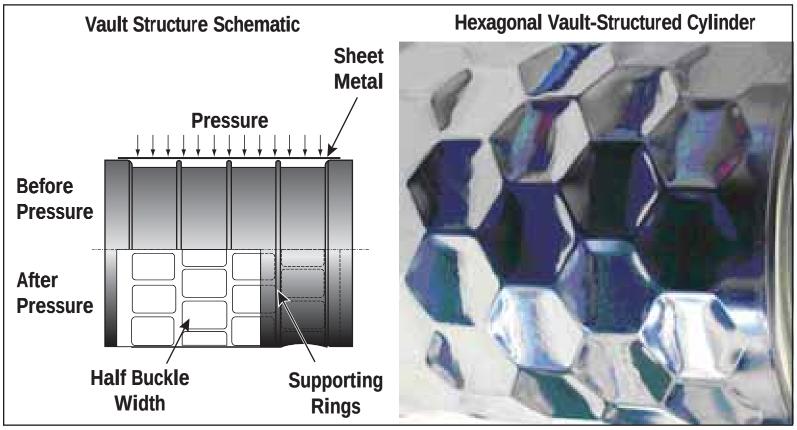


Figure 4