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COMBINED ALUMINUM ROLL-FORMED PROFILES

Aluminum roll-formed profiles in various shapes can act as various straight or bent hollow vehicle body structures, include but not limited to front bumpers, rear bumpers, roof rails, upper A-pillars, front and/or rear longitudinals, and/or seat cross-members, among others, and may be used for various vehicles, including but not limited to commercial vehicles, trucks, busses, vans, and/or railway cars, among others. Aluminum roll-formed profiles may provide strength and/or energy absorption in case of crash events, and may be particularly useful for structures with high crash load requirements. In addition, relatively small bending radii (depending on alloy choice, temper during forming and sheet thickness) may allow for the manufacture of efficient sections with tailored properties. Aluminum roll-formed profiles may be significantly lighter than steel roll-formed profiles at the same performance while also providing significant cost saving potential compared to aluminum extrusions at similar or lower weights.

Aluminum roll-formed profiles may have various characteristics for structural applications. In one aspect, aluminum roll-formed profiles may be manufactured from high strength aluminum sheet alloys such as 6xxx series aluminum alloys and 7xxx series aluminum alloys. The sheet tempers for roll-forming may be T4, T61, T6 or T7x. A typical wall thickness of the aluminum roll-formed profiles may be from 1 mm. to 3.5 mm. Depending on the alloy and specified strength needed for the structure, the aluminum roll-formed profiles may or may not be artificially aged after forming. Aluminum roll-formed profiles may be produced at high rates. In one aspect, forming alone may be at or above 30 m. of profile per minute. Additional processes such as stamping, punching, joining, bending, and/or cutting can be integrated before or after roll-forming as part of a continuous production line.

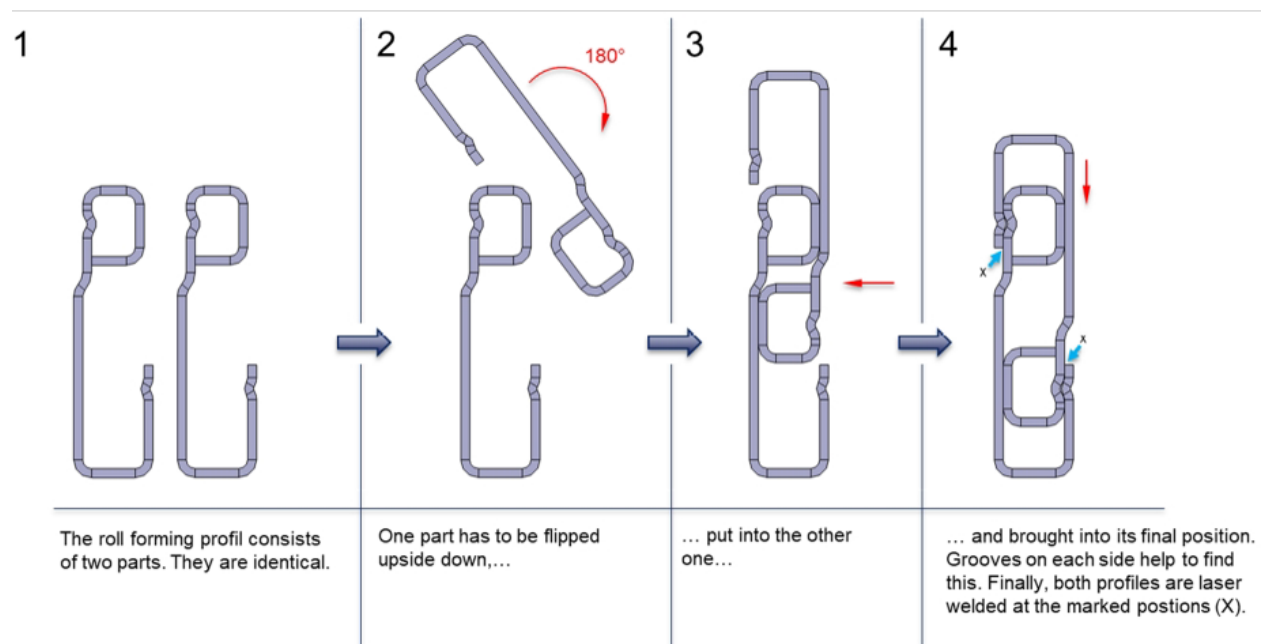
Aluminum roll-formed profiles may also have various critical attributes and functions. In one aspect, a primary function may be to provide structural strength and crash protection (both to occupants and batteries). Aluminum roll-formed profiles may offer a high degree of energy absorption in crash (such as at or above 16 kJ/kg of product in the deformation zone). The aluminum roll-formed profiles may be manufactured with open sections or closed sections. The closed sections may be created by various joining methods depending on accessibility of the joints, including roller seam welding, spot welding, continuous laser welding, stitch laser welding with and without weld wire, adhesive bonding, mechanical joining (e.g., clinching, mechanical interlock, etc.), or combinations thereof. For example, combining remote laser welding with adhesive bonding may provide high productivity and crash worthiness. In certain aspects, aluminum roll-formed profiles may be manufactured with internal ribs and/or may be manufactured with external flanges. Aluminum roll-formed profiles may have a variable cross section over its length (flexible roll-forming), may have a variable wall thickness over its length when starting from tailor rolled sheet, and/or may have a variable wall thickness within the section when material is re-distributed by flow-forming. In some aspects, aluminum roll-formed profiles may have beads and holes introduced by stamping to tailor properties over the length. Aluminum roll-formed profiles may be stacked or assembled with other profiles or stampings to tailor properties over the length. In some cases, aluminum roll-formed profiles may include one or several continuous profiles with discrete reinforcements enclosed.

The crash strength of roll-formed profiles is mainly defined by section design, yield strength, gauge and joints. In a loading direction, the roll-formed profile benefits from as many

walls as possible that are oriented perpendicularly to withstand high forces. Due to manufacturing restrictions, the number of walls may be limited.

To overcome these restrictions, and to provide an improved structure, disclosed are combined aluminum roll-formed profiles that combine identical or similarly-shaped profiles into a new profile. In some aspects, the new profile may not be achievable from a single sheet. Combined profiles represent a cost-effective lightweight solution for a substantial part of vehicle crash structures currently made from aluminum extrusions or steel parts. They may especially be beneficial for electric vehicles needing high performance side crash protection while maintaining low weight and cost.

Preferably, the combined profile consists of only one or two different profiles to lower production cost. One example of a combined profile is illustrated below. In this example, the profile in shape of a “9” is produced twice (step 1), and one of the profiles is rotated by 180° (step 2) and is aligned with the other profile (step 3). The aligned profiles are joined (step 4) using the mechanical interlock and/or laser welding or other joining techniques. In some aspects, the mechanical interlock may ensure correct positioning with minimum gap between the profiles. The resulting combined profile is a closed section with much higher stability than two separate sections of the same shape. For example, in the embodiment illustrated, the combined profile has twice the number of horizontal walls perpendicular to the crash direction (6 total) compared to those of the one-piece roll-formed profile (3 total).



Example Steps for Forming a Combined Profile

Using the technique described above, it may be possible to form more complex profiles and/or profiles that suitable for higher crash forces compared to the one-piece roll-formed profiles. The combined profile may overcome the boundaries set by manufacturing restraints for one-piece roll-formed profiles with regard to sheet material aligned in loading direction. The combined profile also may be used in tight package space, such as a side frame of a battery.