Convertible Top – Lightweight and Made Easy



The convertible top of the Audi A4 convertible has sound and heat-insulating headliner mats and an inner roof

Convertible Top Systems. Innovative and economic solutions can be developed by using plastics for convertible tops and associated systems. Particular advantages are in possible function integration and weight minimisation. In the article some exemplary applications are described.

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The quantities of convertible vehicles produced can vary from 20 000 to 200 000 units depending on vehicle class with running times between four and seven years. With this production volume convertibles belong to the niche vehicle market segment. For niche vehicles it is generally true that investment costs must be kept low due to the small number of units produced. Especially for plastic parts, the choice of manufacturing method has a crucial influence on the investment and thus part costs.

For these small numbers of convertibles plastic parts are often not producible economically using the injection moulding process. On the other hand, however, the part costs rise due to higher material prices and time-intensive manufacturing for alternative processes, e. g. with fibre-reinforced parts. The choice of material and manufacturing method must thus be co-ordinated with the number of items for low volume series.

Performance Specifications for Plastic Parts

Wilhelm Karmann GmbH, Osnabrück/Germany, develops integrated convertible top systems that fulfil the stringent specifications of their customers concerning design freedom, functionality, comfort and durability.

In addition to the usual automobile specifications, noise, wear, sliding friction, mechanical loads during the cover movement as well as suitability for sewing and/or welding must be taken into account for plastic parts in a convertible top. Plastic parts in the steel cover support must not lead to contamination of the CDL bath (CDL: cathodic dip painting) and they must also withstand being loaded in a drying furnace at up to 200 °C for about 20 minutes without damage.

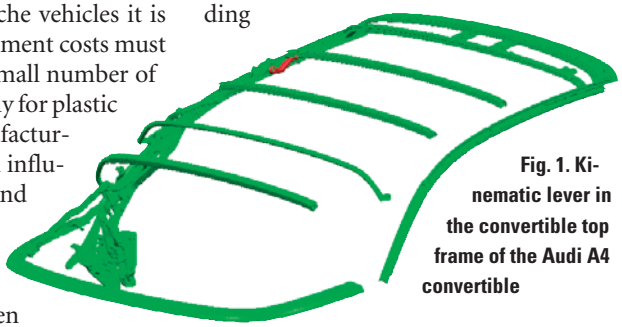


Fig. 1. Kinematic lever in the convertible top frame of the Audi A4 convertible

These requirement profiles must be applied to the part requirements on the top with regard to the specific installation situation. FEM simulation of the manufacturing suitability of the parts and of the computation of certain load cases – as far as possible and meaningful – is used for designing the systems. However, exact simulation is only possible to a limited extent since several characteristics of many types of plastic are presently only insufficiently available. As a result, prototype production and part testing in interaction with associated parts are still an important step in the development process. For the necessary fine tuning experience with convertible tops and the plastic material plays a further crucial role. The following requirements must be fulfilled for the use of plastic parts in convertible covers:

- function throughout the life span (carried out using accelerated time tests with the help of road and component endurance testing),
- function under hot, cold and damp conditions,
- light stability (open-air weathering and sunlight simulation),
- passive safety according to ECE R21,
- avoidance of rattling, creaking and squeaking,
- feel and optics (design),
- weight minimisation,
- protection from abuse,



Fig. 2. Kinematic lever made of metal with clipped plastic shell

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- ease of assembly and fabrication (high proportion of manual work during the final assembly),
- processability
- ability to sew, weld and glue as well as
- consideration of the available design confines (for closed and stored tops, for example, reinforcement ribs of planar plastic parts are possible to a limited extent).

Function Integration and Low Weight

There are essentially two different types of convertible tops. At present, the largest numbers of produced units are textile tops with metal supports – so-called softtops. The trend, however, is toward retractable hardtops (RHT). They are solid folding roofs made of metal or a combination of metal and glass, e. g. for the present Renault Megane CC. Wilhelm Karmann GmbH developed the roof module for this vehicle and supplies it in series production. The design of the roofs depends very strongly on the motor vehicle type and position in the market: Roadster tops differ clearly from tops for convertibles in the premium segment through a comparatively spartan design. Hence, the Audi A4 convertible and Mercedes CLK convertible vehicles manufactured by Karmann have noise and heat insulating pad mats and an interior headliner.

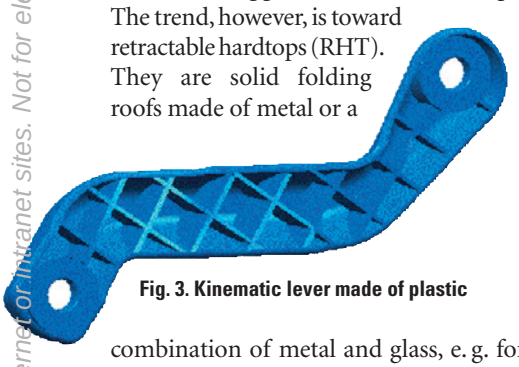


Fig. 3. Kinematic lever made of plastic

Different requirements on the plastic parts result for each type of convertible top. Nearly all top types have linings on which similar requirements are made as with column linings and roofs for closed vehicles. However, for these linings the concepts must additionally be designed so that overlaps are impossible when the top is in motion.

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Softtop: In principle a softtop consists of three textile layers: the polyester PAN fibre cover material with rubber coating, the pad mat made of polyester fleece and the headliner material. The textile is stretched over a frame made of metal and/or plastic. Trim parts, seals, closure systems, electrical connections and hydraulics for actuation and comfort improvement are among additional components of the convertible top system.

The development and manufacture of a textile top require procedures different from classical body development. The deep-drawing behaviour of metal plates and their deformation under load, for example, can be simulated much better with the help of FEA than the storage behaviour and complex material stresses of a convertible top.

The textile materials are attached to the frame with plastic profiles, piping or shaped parts. They are sewn on or welded at the edges of the textile layers. The parts must not fail despite damage by sewing. They must be highly heat deformation resistant in order to give the interior headliner and covering a certain outline and a certain path when opening and closing the top. Polyethylene (PE), polypropylene (PP), polyamide (PA) or (PC+ABS) blends are some of the materials used, since they can be sewn well and thus are tough and tear propagation resistant. Special PA, PPA and (ABS+PC) types are used for more highly loaded injection moulded parts. For instance, at the bonded rear window the roof is attached with an injection moulded plug-in frame made of a (PC+ ABS) blend or PPA.

An example of force transmission in the convertible top frame is the kinematic lever. It was originally developed as a plastic shell clipped onto the metal linkage. The shell served to optimise sliding during the headliner motion. The steel linkage part and shell were united in a single part made of the high performance plastic PPA. The function of integration into a single part makes high power transmission possible with a clear improvement in sliding without the risk of release of the clipped on shell. In addition the frame with the part made of PPA is suitable for the CDP finish (Figures 1 to 3).

The so called partition wall is a folding part in the trunk into which the top is folded when the cover is closed, for example in the Chrysler Crossfire convertible, the wall can be folded up by hand and fastened with Velcro fasteners to the rear of the trunk. Thus the trunk volume can be increased from 124 to 221 litres (according to VDA). The light GMT material used for this partition is characterised by light weight and high rigidity. Contours can be formed easily. It can be manufactured using low pressures. Mould investments are comparatively low. The trimming can be integrated and a carpet surface can be pressed along with the part (Figures 4 and 5).

Retractable Hardtop (RHT): For the RHT in contrast to the softtop the interior is not formed by the stretched interior headliner, but by pillar trim parts similar to that in a closed vehicle. In addition, the Renault Megane CC, for example, has a plastic parcel shelf integrated into the motion of the RHT. It consists of two (PC+ABS) shells that are welded to an assembly with their linkage flaps. With the RHT open, the flaps cover the linkage openings of the vehicle. They dip under the parcel shelf when the RHT is closed in a rotating motion transmitted by bowden cables. This is done using a sliding block in a plastic casing. Due to stringent requirements concerning dimensional stability and rigidity as well as optimal slip characteristics all parts of the linkage flap consist of partly aromatic PA with glass and/or carbon fibre reinforcement (Fig. 6).

Future Developments

Already today there are many demanding applications for plastics in the convertible top in addition to the trim parts and seals. In particular, heat deformation resistant, low friction, tough and strong as well as high-strength plastics such as (PC+ ABS), PBT, POM, PA and PPA are in demand. Depending on the number of parts economical and high-quality plastic parts for convertible tops can be manufactured by injection moulding as well as R-RIM, pressing or deep-drawing.

The development of new procedures and plastic materials makes it possible to reduce the number of parts and the convertible top weight as well as to further increase passenger comfort. High performance plastics already available on the market are finding new applications in convertible covers. High-strength crash withstanding short or long fibre reinforced PA can replace die-cast metal in many applications and contribute to weight reduction at the same time. Mixed designs using metal and plastic or different plastics in two component or insert technology make further applications in the highly loaded convertible top frame conceivable. Extruded aluminium frame

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Fig. 4. Partition wall in the Chrysler Crossfire convertible with opened top



Fig. 5. With the cover closed the partition in the Chrysler Crossfire convertible is folded downward by hand and then rearward to the rear wall of the trunk and fastened using Velcro fasteners



Fig. 6. The parcel shelf of the Renault Megane CC in motion

profiles can be eliminated by integrating the sealing function into convertible top frame parts made of plastic. Tight building confines again require new motion concepts that can often be realised only with plastics or mixed constructions. ■

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