Effect of the Rolling Direction on Mechanical Properties of Metal-Polymer-Metal Sandwich Panels

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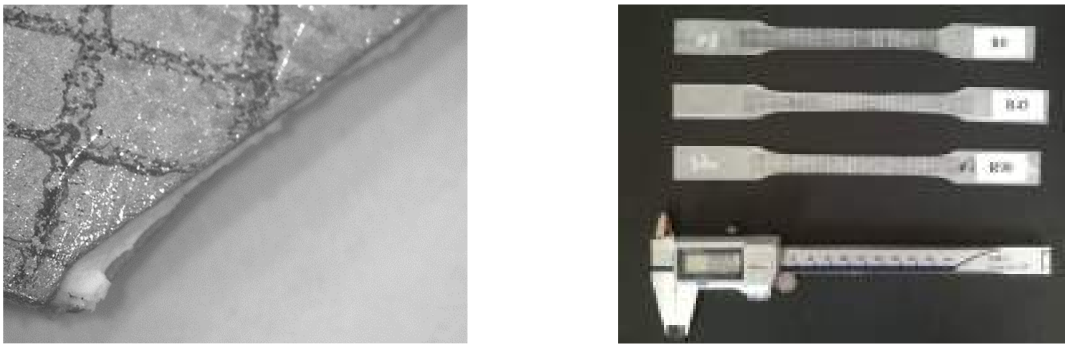
Abstract. In recent years, many sectors of the manufacturing industry, such as the automotive, aerospace, aeronautical and transport ones, are pushing towards an increasingly research focused on the development of new lightweight materials, in response to the growing need for lighter, safer, more environmentally friendly, more performant and cheaper products. To this purpose, metal-polymer-metal (MPM) sandwich panels, composed by a polymer core of a thickness equal to about 0.3-1.0 mm, between two steel face sheets, each 0.2-0.3 mm thick, offer several advantages as compared to monolithic metal sheets [1]. In particular, MPM sandwiches lead to a significant weight-reduction and an increase in sound vibration and damping characteristics [2]. Moreover, they are characterized by attractive costs [3]; consequently, MPM sandwich panels have been considered as a potential candidate in the substitution of monolithic sheets used in vehicle body panels and have been implemented to reduce cabin noise by several automotive manufacturers [4]. The obtaining of complex shapes in sandwich panels by forming operations, such as for automotive panels or structural parts, is critically affected by the occurrence of forming failures. It is well known that the currently used methodology based on Finite Element Method, used to predict the occurrence of these defects, allows to simulate forming processes with an accuracy that is strongly related to the precise knowledge of the input data, such as constitutive equations, anisotropy coefficients, etc. Many researchers have investigated the mechanical properties of monolithic metal sheets, whilst few studies on the mechanical behavior of sandwich panels are available in literature [5].

In this framework, the present work aims at studying the effect of rolling direction (RD) on the mechanical properties of sandwich panels with a metal-polymer-metal structure (steel sheets and plastic core layer of 0.3 mm each). To this purpose, uniaxial tensile tests were performed at room temperature on a servo-hydraulic testing machine. Standard tensile specimens were obtained by water jet machining at different angles to rolling direction, namely 0°, 45° and 90° (conditions R0, R45 and R90, respectively). The experimental results were plotted as nominal stress (s) versus nominal strain (e) curves. Each experimental condition was repeated at least three times.

Fig. 1 shows typical fractured tensile samples in which fractured surfaces at about 30° - 40° to the perpendicular to the loading direction can be observed. Typical s-e curves of MPM sandwich panels, at different loading direction with respect the RD, are shown in Fig. 2. Irrespective of the fiber orientation, the nominal stress monotonically increases with nominal strain, in a wide range of homogeneous pre-necking deformation. After reaching the peak value, the flow stress does not exhibit any appreciable decrease with increasing strain before failure, and the tensile samples generally show a significant post-necking deformation. As far as the effect of the fiber orientation to rolling direction is taken into account, an anisotropic behavior of MPM sandwich panels can be observed; in particular, nominal stress values obtained on samples at 45° to rolling direction are the lowest as compared to those obtained on specimens at 0° and 90° with respect the RD. A

slight effect of rolling direction on ultimate tensile strength can be observed on specimens obtained at 0° and 90° to the rolling direction. Furthermore, the elongation to failure exhibited by the sample at the R45 condition is higher than those at R0 and R90. Finally, samples characterized by the loading direction parallel to the RD show the lowest ductility levels.



(a) (b)

Fig. 1. (a) Magnification of polymer core between the two steel sheets in a fractured surface, and (b) effect of the rolling directions on fractured tension tested samples.

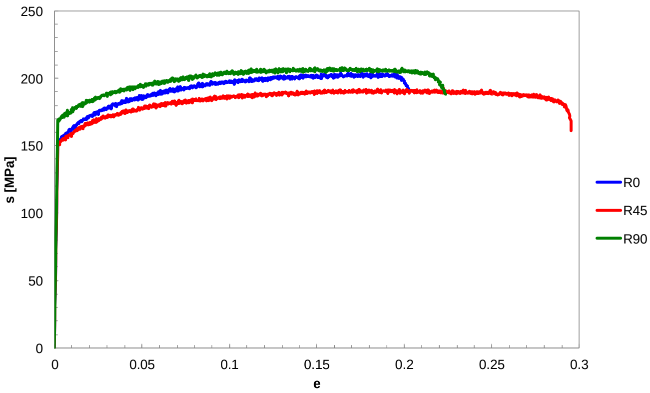


Fig. 2. Effect of fiber orientation on typical nominal stress vs. nominal strain curves of metal-polymer-metal sandwich panels.

REFERENCES

1. B. Harris. A perspective view of composite materials development. Materials & Design 1991, 12(5):259-272.
2. Y.-M. Huang, D.-K. Leu. Finite-element simulation of the bending process of steel/polymer/steel laminate sheets. J. Mater. Process. Technol. 1995, 52:319–337.
3. I. Burchitz, R. Boesenkool, S. van der Zwaag, M. Tassoul. Highlights of designing with Hylite – a new material concept. Mater Des 2005; 26(4): 271–279.
4. R.B. Ruokolainen, D.R. Sigler. The effect of adhesion and tensile properties on the formability of laminated steels. J. of Materi Eng and Perform 2008, 17: 330-339.
5. K.F.Karlsson, T. Aström. Manufacturing and applications of structural sandwich components. Composite Part A 1997, 28A:97–111.