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Determination of Mechanical Properties of Magnesium Alloys and Composites by Small Punch Testing

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Abstract: Tests on miniature samples are increasingly used for the testing of mechanical properties of materials available in small volumes (non-destructive or semi-destructive approach). Small punch testing at constant deflection rate (SPT-CDR) of selected magnesium alloys and composites was performed at room temperature. Mechanical properties (yield strength, ultimate strength and ductility) were evaluated from SPT and correlated with results of uniaxial tensile tests (UTT). SPT characteristics were converted to uniaxial tensile properties by empirical formulas available in the literature. New formulas more appropriate for magnesium alloys were suggested.

Introduction

Principle of the method is a penetration of small puncher through thin disc (thickness up to 0.5 mm, diameter up to 10 mm) placed on a ring until the disc bursts (see Fig. 1). There are two main SPT approaches i) Constant Displacement Rate (CDR) – puncher moves with constant rate. This is an analogy of UTT. ii) Constant Force (CF) - puncher penetrates under a constant force *F*. This test is an analogy to conventional constant load creep tests.

Certain weakness of this method presents complicated clarification of the relations between SPT and UTT. Most of previous correlation formulas were based on testing steel specimens; therefore confirmation of these empirical formulas on different materials is appropriate.

Five magnesium alloys (AZ31, AZ61, AZ91, WE54, MgZnMn) and one composite with magnesium alloy matrix (AZ91 + 20% saffil) were chosen as an experimental material for the study.

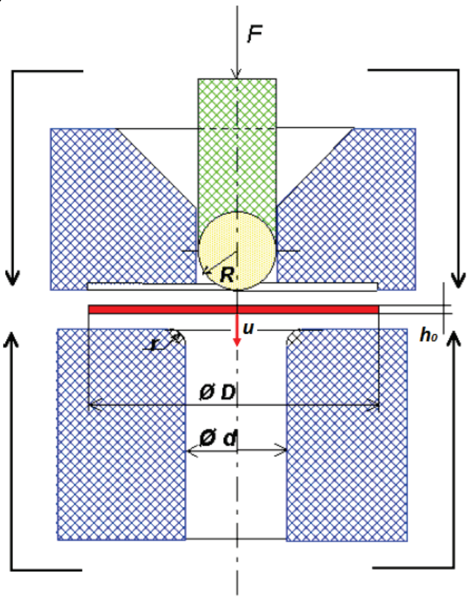

Fig. 1: Scheme of a test arrangement for SPT.

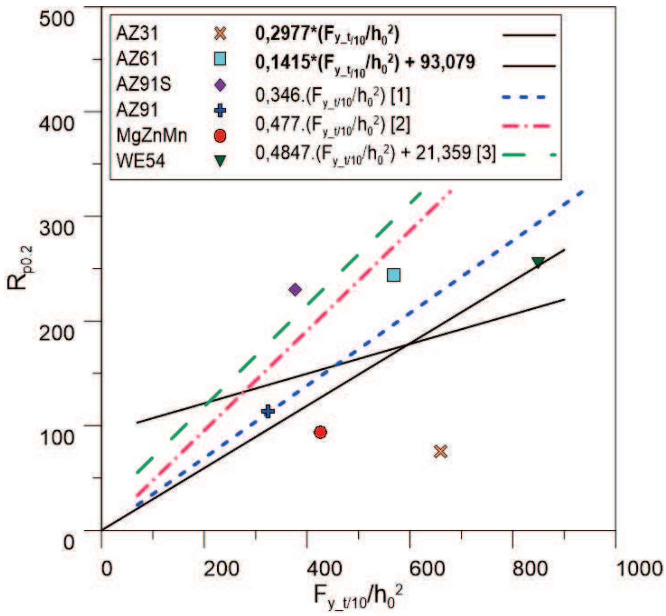

Fig. 2 Dependence of UTT yield strength on SPT yield strength.

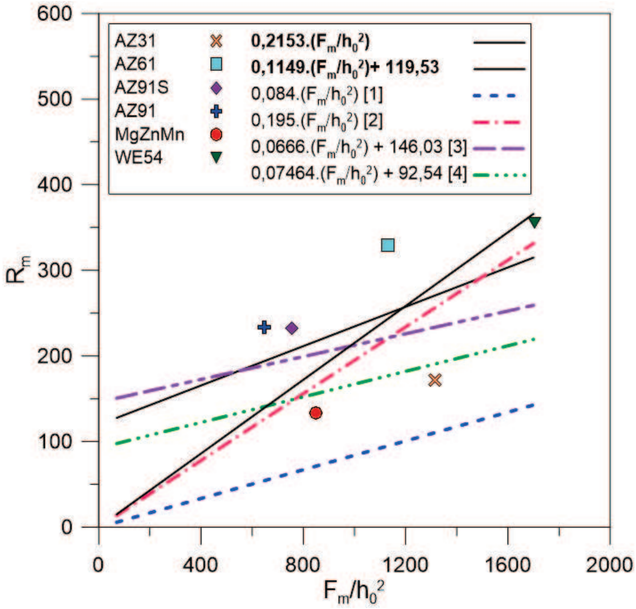

Fig. 3: Dependence of UTT ultimate strength on SPT yield strength with h_0^2 parameter.

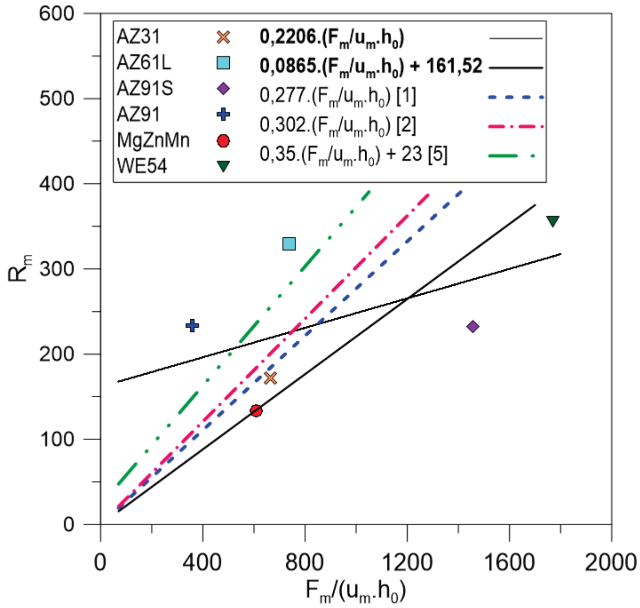

Fig. 4: Dependence of UTT yield strength on SPT yield strength with $h_0.u_m$ parameter

Discussion

Dependence of UTT strength on strength acquired from SPT tests for studied Mg alloys is shown in Figs. 2 - 4. Large scatter of data is apparent. Measured data were fitted by empirical formulas from literature [1-5] and by new linear regression with both zero and non-zero intersection with Y axis. Non-zero intersection is in contrary to physical presumption of zero strength R_m at zero SPT force F, nevertheless these formulas are suitable approximation at some test results range.

The macroscopic appearance of fracture surfaces exhibited two main phenomena – "star" fracture and "cap" fracture, which reflects brittle resp. ductile character of the material. Materials with "cap" fracture lie in Figs. 2 - 3 below regression lines, conversely those with "star" fracture lie above regression lines. In Fig. 4 it can be seen that deflection u_m at maximum force F_m is shifting ductile alloys (e.g. MgZnMn, AZ31) closer to regression lines in contrary brittle composite (AZ91 + 20% saffil) was shifted significantly farther. These can be reasons why it is unrealistic to define universal empirical formula. Therefore a more advanced approach to define correlation between UTT and SPT data might be to sort materials by ratio of "star" to "cap" fracture, eventually according to microscopical evaluation of brittle/ductile ratio of fracture appearance.

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