Thesis booklet

Mechanical behavior of metal matrix syntactic foams during cyclic and high strain rate compression

PhD dissertation

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Ceramics hollow spheres filled aluminum or aluminum alloy matrix syntactic foams were investigated in my PhD work. These materials can be used in wide range of field: parts of aerial or automotive transport equipment, packing or wrap material. Due to the long way mechanical energy absorption they can be used as crashing zone parts or protective cover of cars.

In the point of view of the potential applications it is important to know the fatigue and the compressive properties of these materials. Therefore, the main goals of my PhD work were to perform and evaluate the fatigue tests of the ceramics hollow spheres filled aluminum or aluminum alloy matrix syntactic foams. Cylindrical specimens were used and the loading was sinusoid compression. For the evaluation of the measured data Weibull analysis was used due to the stochastic behavior of the tests. Based on the results, it can be concluded that the matrix material has a main role in the fatigue properties, the softer matrix resulted larger cycles number at a given load level. The difference of the cycle number at fracture was decreasing with the decreasment of the loading level. The damage mechanism of the ceramics hollow spheres filled aluminum or aluminum alloy matrix syntactic foams depends on the connections of the compression strength of the matrix and the hollow spheres.

The quasi-static and the high strain rate compression of the investigated ceramics hollow spheres filled aluminum or aluminum alloy matrix syntactic foams was the other main test series in my PhD work. The high strain rate tests were performed with Split Hopkinson pressure bar. During the tests, high speed camera was used to observe the sample. The results are highly important to the further application of these foam materials at crashing zones. Based on the results, it can be concluded that the material and the heat treatment of the matrix and the rate of the strain has a main role in the compression properties. Due to the dynamical compression, the damage mechanism of the investigated ceramics hollow spheres filled aluminum or aluminum alloy matrix syntactic foams was significantly different from the quasi-static state's.

1th Thesis *[4] [5] [7] [9] [13]*

According to the performed fatigue tests (compressive sinusoid loading, f = 10Hz, R = 0.1, D = 8.5 mm, H/D = 1.5), it was concluded that the typical increasing of the deformation was at 2 % of the engineering strain, which is the damage limit of the materials as well. Based on this, it can be stated that the ε = 2 % engineering strain can be used as a failure criterion to ceramics hollow spheres filled metal matrix syntactic foams.

2nd Thesis *[4] [5] [7] [9] [13]*

Fatigue tests on ceramics hollow spheres filled Al99.5 and AlSi12 matrix material syntactic foams by sinusoid compressive load (f=10Hz, R=0.1, D = 8.5 mm, H/D = 1.5) were completed. According to the statistical evaluation of the large number of samples which were tested, the SD-N relationships of these materials were created, which can be written by the following equations:

$S_{Al99.5-GC} = 43.1\ (MPa) - 1.48 \cdot lgN_D$ *in the case of Al99.5-GC*

and

$S_{AlSi12-GC} = 87.3\ (MPa) - 3.33 \cdot lgN_D$ *in the case of AlSi12-GC type syntactic foam.*

The statistically evaluated stress value for for 2·106 cycles are 34.1 MPa in the case of Al99.5-GC and 66.8 MPa in the case of AlSi12-GC type syntactic foam.

3rd Thesis *[5] [6] [7] [9] [13]*

According to the microscopic investigations of the Al99.5 and AlSi12 matrix - ~64 vf% Globocer (GC) type syntactic foams (D = 8.5 mm, H/D = 1.5) after cyclic loading, it can be concluded the soft, unalloyed matrix (Al99.5) deformed plastically before the crush of the hollow spheres that resulted in a shear band inclined ~45° to the direction of the compressive load. In the case of harder, Si alloyed matrix material the hollow spheres fractured before the deformation of the matrix material that resulted in cone-like shear bands and a lenticular in shape damage zone. Far from the damage zone the foam structure was remained unharmed.

4th Thesis *[3] [6] [8]*

According to the results of the performed high strain rate tests on Al99.5-O, AlSi12-O, AlMgSi1-O, AlCu5-O, AlMgSi1-T6 and AlCu5-T6 ceramics hollow spheres filled metal matrix syntactic foams (D = 12.7 mm, H/D = 1), it can be concluded that the absorbed energy at 933 s-1 strain rate (up to ε = 2.5 %) is twice, at 2629 s-1 strain rate (up to ε = 8.1 %) is three times as large as in the case of the quasi-static compression. The main reason of the increase in the measured value was caused by the loaded volume of material, which size was increased due to the dynamic load. The increase of the strength of the matrix materials also increases the amount of the absorbed energy, therefore the AlCu5-T6 ceramics hollow spheres filled metal matrix syntactic foams reached the highest value of that.

5th *Thesis [3] [6] [8]*

The dynamic compression to the Al99.5-O, AlSi12-O, AlMgSi1-O, AlCu5-O, AlMgSi1-T6 and AlCu5-T6 ceramics hollow spheres filled metal matrix syntactic foams (D = 12.7 mm, H/D = 1) caused structural damages in the whole specimen volume in contrast to the quasi-static state, where the damage was local. At the beginning of the deformation, the hollow spheres cracked parallel to the direction of the load and the matrix materials cracked as well between the cells. At the latter stage of the deformation the cracked hollow spheres fell into pieces and the matrix material moved into the cells. The shock wave due to dynamic load was standing in the background of these phenomenon, which affected the whole volume of the specimen.

LIST OF OWN PUBLICATIONS

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[2] Attila Szlancsik, **Bálint Katona**, Kornél Májlinger, Imre Norbert Orbulov: Compressive Behavior and Microstructural Characteristics of Iron Hollow Sphere Filled Aluminum Matrix Syntactic Foams, Materials 8 (2015:11) 7926-7937

[3] Kyle Myers, **Bálint Katona**, Pedro Cortes, Imre Norbert Orbulov: Quasi-static and high strain rate response of aluminum matrix syntactic foams under compression, Composites Part A: Applied Science and Manufacturing 79C (2015) 82-91

[4] Mehdi Taherishargh, **Bálint Katona**, Thomas Fiedler, Imre Norbert Orbulov: Fatigue properties of expanded perlite / aluminum syntactic foams, Journal of Composite Materials 51 (2017:6) 773-781

[5] **Bálint Katona**, Gábor Szebényi, Imre Norbert Orbulov: Fatigue properties of ceramic hollow sphere filled aluminium matrix syntactic foams, Materials Science and Engineering A-Structural Materials Properties Microstructure and Processing 679C (2017) 350-357

[6] **Bálint Katona**, Imre Norbert Orbulov: Structural Damages in Syntactic Metal Foams Caused by Monotone or Cyclic Compression, Periodica Polytechnica Mechanical Engineering Periodica Polytechnica-Mechanical Engineering 61 (2017:2) 146-152

[7] **Katona Bálint**, Szebényi Gábor, Orbulov Imre Norbert: Fémmátrixú szintaktikus fémhabok fáradási tulajdonságai, Bányászati és Kohászati Lapok – Kohászat 148 (2015:2) 30-33

[8] **Katona Bálint**, Orbulov Imre Norbert: Kerámia gömbhéjakkal töltött szintaktikus fémhabok kvázi-statikus és nagy alakváltozási sebességű nyomóvizsgálata, Bányászati és Kohászati Lapok – Kohászat 149 (2016:3) 30-35

[9] Imre Norbert Orbulov, **Bálint Katona**, Gábor Szebényi: Fatigue Properties of Metal Matrix Syntactic Foams, In: Proceeding of 3rd Conference on Cellular Materials (CELLMAT2014), 22-24th October 2014, Dresden, Germany (CD-n jelent meg).

[10] Keresztes Zoltán, Ladányi-Pára Gergely, **Katona Bálint**: Üveggömbhéj erősítésű alumínium mátrixú szintaktikus fémhab kvázi-statikus nyomóvizsgálata, In: Proceedings of the XXI-th International Scientific Conference of Young Engineers, 2016.03.17-2016.03.18. Kolozsvár: Erdélyi Múzeum-Egyesület (EME), (2016) 209-212.

[11] Ladányi-Pára Gergely, Keresztes Zoltán, **Katona Bálint**: Lehet-e a fémhab köszörűanyag?, In: Proceedings of the XXI-th International Scientific Conference of Young Engineers, 2016.03.17-2016.03.18. Kolozsvár: Erdélyi Múzeum-Egyesület (EME), (2016) 253-256.

[12] **Katona Bálint**, Szlancsik Attila, Orbulov Imre Norbert: Kerámia gömbhéjakkal töltött szintaktikus fémhabok törésmechanikai vizsgálata, In: Proceedings of the XXII-th International Scientific Conference of Young Engineers 2017.03.23-2017.03.24. Kolozsvár, Erdélyi Múzeum-Egyesület (EME), (2017) 211-214.

[13] **Katona Bálint**, Szebényi Gábor, Orbulov Imre Norbert: Behaviour of metal matrix syntactic foams under cyclic loading, Proceedings of the 4th International Scientific Conference on Advances in Mechanical Engineering. Konferencia helye, ideje: Debrecen, Magyarország, 2016.10.13 2016.10.15.pp. 277-282.(ISBN:978-963-473-944-9)1