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BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
FACULTY OF MECHANICAL ENGINEERING

**SUMMARY OF PHD DISSERTATION**

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# Aluminium matrix composite wires and double composite-structures

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## Research objectives

The objectives of my research were developed by the followings:

1. Determination of the effect of infiltration pressure on the properties of Nextel™ 440/Al composite wires and describing the relationship between them. Additionally the other aims are the theoretical calculation of the threshold pressure and its comparison with the measured values.
2. Examination of the responses of the composite wires during long term heat treatment and the connection between them, because the temperature of high voltage electric power cables can reach 300°C. So it is important to know if there is degradation in the mechanical and electrical properties.
3. Proving the appropriateness of Nextel 440/Al composite wires to reinforce double composite-structures and determination of the bending strength increasing.

## Completed research work and results

Through this dissertation the manufacturing and examination of composite wires and double composites were carried out. During the production of the composite wires with 1.0 and 2.0mm diameters, one of the most important manufacturing parameter; the infiltration pressure was changed, and its effect on the matrix fraction and on the stability was examined. After the evaluation of the results from my experiment, I came to the conclusion that the essential threshold pressure value interval, to start the infiltration of the composite wires is within the range 0.62-0.83 MPa. The wires with 1.0 and 2.0 mm diameters are in the range of 0.83-1.63 MPa and 0.83-2.07 MPa respectively. With the use of linear correlations, these values demonstrated a good and understandable relationship with the relative matrix fraction. The upper limit of the pressure range examined resulted with fibre rupture, which in the case of the 2 mm wires, occurred using the higher pressure value.

My infiltration results were compared to mathematical models, i.e. White-Mortensen model and Kaptay model. For the parameter range studied, the White-Mortensen model gave the result 0.12-0.50MPa, while the Kaptay model 0.2-

0.77MPa. The interval of 0.62-0,83 MPa determined from my experiments only shows overlapping with the Kaptay model. Therefore, the Kaptay model is suitable for the mathematical approach of my trial results.

The tensile strength was also measured on samples taken from the composite wires produced using different infiltration pressures. In both cases of composite wires (i.e. 1.0 and 2.0 mm diameter) the result of the representation of the tensile strength values, as a function of the pressure, yielded a maximum graph. With the 1.0 mm diameter type wire, the highest tensile strength value was achieved at a pressure of 1.03 MPa, yet with the 2.0 mm diameter wire, this infiltration pressure value was 1.86 MPa.

The composite wire can also be used as a reinforcing material for high tension cables. However, this promising application option demands several requirements from the composite wire. The reason for this is that, as well as the mechanical stress, the loaded cables are also affected by a significant and continuous thermal stress caused by the Joule heat that is produced by the flow of current. Therefore, the changes to the mechanical and electrical properties, caused by lasting heat, were also examined. The experiments showed that the heat treatment did not affect the resistivity. In addition, the mechanical properties only become significantly poorer at 500°C or greater. Another potential field of application of the composite wire is as a reinforcing material for double composites. During these trials, the production of composite wire reinforced double composite, using gas pressure infiltration and gravity casting, was successfully achieved. A measurable increase in strength was registered on the manufactured samples.

## Theses (New scientific results)

**1. theses [1,2]**

By taking measurements I proved that the threshold pressure interval, necessary for the continuous infiltration of the Nextel™ 440/Al composite wires, is 0.62-0.83 MPa. Above this threshold pressure value, the relation between the volumetric part of the aluminium and the infiltration pressure values is sufficiently linear and therefore acceptable in practice. This statement is valid for a pressure interval of 0.83 MPa-1.63 MPa and 0.83 MPa-2.07 MPa with the 1.0 and 2.0 mm diameter composite wires respectively.

**2. theses [1,2]**

The 0.62-0.83 MPa interval for the threshold pressure was compared with two theoretic models using the following parameters: the diameter of the fibres 11.35 ±3.15 µm, the volumetric part of fibres 51.7 ±8%, the surface tension of the melt 0.87 ±0.03 $J/m^2$, and the contact angle of the melt on the fibres 135 ±5°. The results of the White and Mortensen model were 0.12-0.50 MPa and 0.20-0.77 MPa with the Kaptay model. The latter values overlap with the results from my experiments, while the first does not. Therefore the Kaptay model is more suitable for the mathematical approach of my own trial results.

**3. theses [1,2]**

In the range examined, the tensile strength - infiltration pressure (matrix fraction) function for the Nextel™ 440/Al composite wires results in a graph showing a maximum value. With the 1.0 mm diameter type wire, the highest tensile strength value was achieved at 1.03 MPa, while with the 2.0 mm diameter wire, this infiltration pressure value was 1.86 MPa.

**4. theses [3,4]**

It was demonstrated, that the static and dynamic loading capability of the composite wires were significantly reduced after only 100 hours, while maintaining a temperature of 500°C and above. Notably, after 1000 hours, a 50% reduction can occur.

**5. theses [3,4]**

It was proved by means of measurement of the results, that the electrical resistivity of the Nextel™ 440/Al composite wires still remained consistent following the heat treatment on 500°C for 1000 hours. The resistivity of the composite wires (1.6 mm diameter), containing an average of 55% of ceramic fibres (by volume), produced with an infiltration pressure of 1.63 MPa, is 0.007 ±0.0006 $\Omega mm^2/m$.

**6. theses [5-10]**

It was demonstrated from the trial results that for the production of the AlSi12 matrix double composite reinforced with Nextel™ 440/Al composite wire both the gravity casting and the gas pressure infiltration method are suitable. The gravitation casted double composites showed 30% increasing of bending strength in case of 3.6% volume fraction of composite wire reinforcement, while the gas pressure infiltrated double composites showed 17.9% increasing of bending strength in case of 5,9% volume fraction of composite wire reinforcement.

## Publications of the new results


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[2] **Kientzl I**, Dobranszky J, Nemeth A: Effect of the infiltration pressure on the properties of composite wires. (OATK7) Materials Science Forum xxx-xxx, (2010) xxx-xxx, benyújtva.

[3] **Kientzl I**, Dobránszky J: Kompozithuzalok tulajdonságainak változása tartós idejű hőkezelés hatására. Tóth T (szerk.): Előadások, XXII. Hőkezelő és Anyagtudomány a Gépgyártásban Országos Konferencia és Szakkiállítás, Balatonfüred, 2006. október 4-6. GTE Hőkezelő Szakosztály, 115-117.

[4] **Kientzl I**, Dobranszky J, Ginsztler J: Heat treatment and impact testing of composite wires. Key Engineering Materials Vols. 345-346 (2007) pp. 1273-1276.

[5] **Kientzl I**, Dobránszky J: Production and Examination of Double Composites. Materials Science Forum, 537-538, (2007) 191-197.

[6] **Kientzl I**, Orbulov I, Dobranszky J, Nemeth A: Mechanical behaviour Al-matrix composite wires in double composite structures. Advances in Science and Technology, 50 (2006) 147-152.

[7] **Kientzl I**, Orbulov I, Dobranszky J, Nemeth A: The processing and testing of aluminium matrix composite wires, double composites and composite blocks. ECCM12, 12th European Conference on Composite Materials. Biarritz, 29th August – 1st Septemberr 2006, (CD-ROM) docs\192.pdf.

[8] **Kientzl I**, Orbulov I: Fémmátrixú kompozithuzalok, dupla kompozitok és kompozit tömbök tulajdonságai. Anyagok Világa VII. évfolyam 1. szám, 2007. Június
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[10] **Kientzl I**, Dobranszky J: Methods of double composite fabrication. Gépészet 2008, Proceedings of Sixth Conference on Mechanical Engineering.

## Other publications

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[12] **Kientzl I**, Dobránszky J, Ginsztler J: Effect of Production Parameters on the Properties of Composite Wires. In: Papp É, Mácsay I, Holubetz L (szerk.) Gépészet 2006 Proceedings of Fifth Conference on Mechanical Engineering, Budapest University of Technology and Economics, National Technical Information Centre and Library, Budapest, 2006, http://152.66.34.17:4001/pdf/kientzl_dobranszky_effectproduction.pdf; CDROM (ISBN 963 593 456 3)

[13] Orbulov I, **Kientzl I**, Nemeth A: Fémhabok és kompozitok előállítása infiltrálásos eljárással. BKL Kohászat 140. évfolyam (2007/5).

[14] **Kientzl I**, Dobranszky J, Blucher J, Nemeth A, Orbulov I: Mechanical properties of composite wires and double composites. ESMC 2006. 6th European Solid Mechanics Conference. Budapest, 28 August–1 September 2006.

[15] **Kientzl I**, Dobranszky J, Blucher JT: Failure of metal matrix composite wires and double composites. Proceedings of the Second International Conference on Engineering Failure Analysis. September 12-15, 2006 Toronto, Canada. P2.18.