Effect of structure ordering on the abrasive wear of Fe-Al (B2) type intermetallic coatings after D-gun spraying and high temperature annealing

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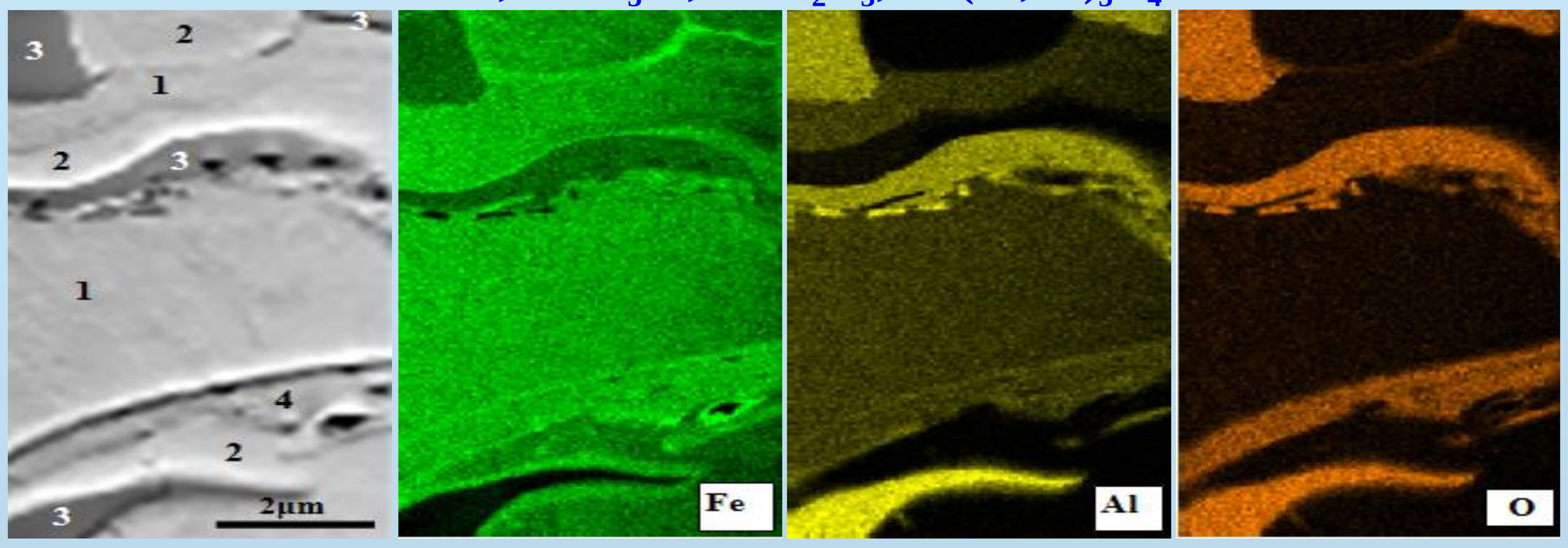
INTRODUCTION

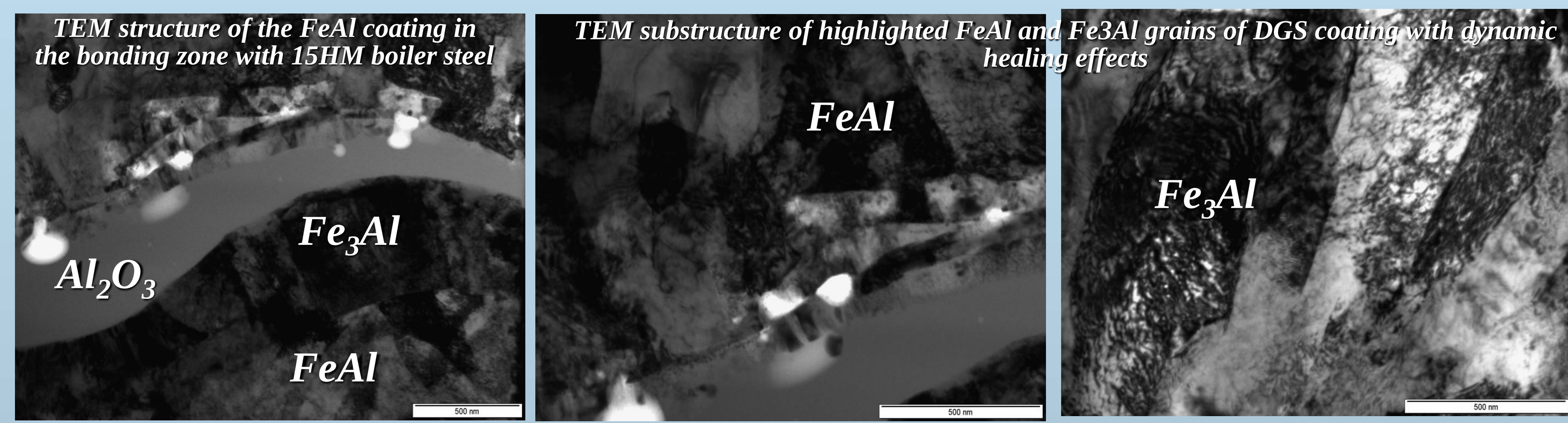
The relationship between hardening, crystallite size, and long-range ordering (**LRO**) was considered in analyzing the impact of the degree of structural ordering on the tribological properties of **FeAl(B2)** type coatings sprayed by the gas detonation method (**DGS**). This includes both the self-decomposing Fe-Al(B2) type powder and the sprayed coatings, which were annealed at 800°C for 25, 50, and 100 hours, respectively, and then subjected to abrasive wear with loose abrasive and dry friction conditions. The stability of the homogenized structure was determined with the effect of intense recovery without signs of recrystallisation as the heating time was extended in ongoing thermal processes. Despite the decrease in microhardness caused by the residual stress relaxation during annealing, the treatment Fe-Al coatings still maintain a high level of hardening due to the high LRO degree, which significantly improves the wear resistance of the coatings. Additionally, a factor contributing to resistance to abrasive wear, high-temperature oxidation, and protection against environmental corrosion is the ability to form a complex and passive Al_2O_3 protective layer. Under DGS conditions, aluminium oxides are formed in situ along the grain boundaries as submicron amorphous sublayers with a geometry similar to the intermetallic matrix grains without causing microcracks and a decrease in the cohesive strength of the FeAl grains. Such a desirable structure, constituting a specific type of composite, can be obtained in the DGS process with the supersonic flow of the metallizing stream, where under certain D-gun spraying parameters, the FeAl powder particles do not melt and are in a very highly softened state, forming a coating with negligible porosity below 1%.

Key words: *D-gun spraying, FeAl(B2) intermetallic coatings, long-range ordering, oxide ceramics, resistance wear*

Characteristic phase sequence in the D-gun sprayed FeAl coating with the component element distribution

1- FeAl; 2- Fe_3Al; 3- Al_2O_3; 4- $(Fe, Al)_3O_4$

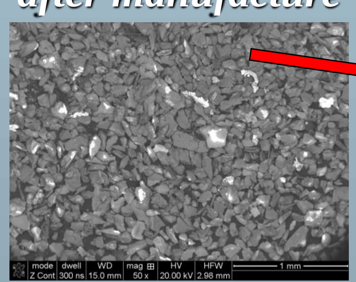




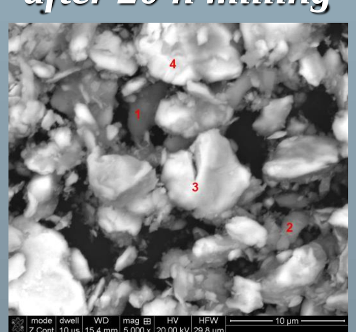
C. Senderowski, Iron-aluminium intermetallic coatings synthesized by supersonic stream metallization, 2015, Warsaw- Poland, 268 pages, ISBN: 978-83-7798-227-3

FeAl self-decomposing powder

after manufacture

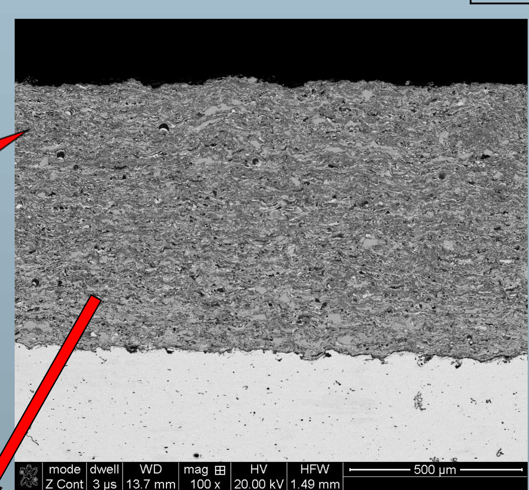


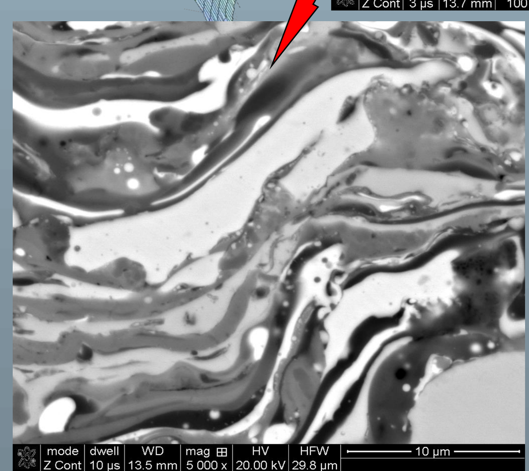
after 20 h milling

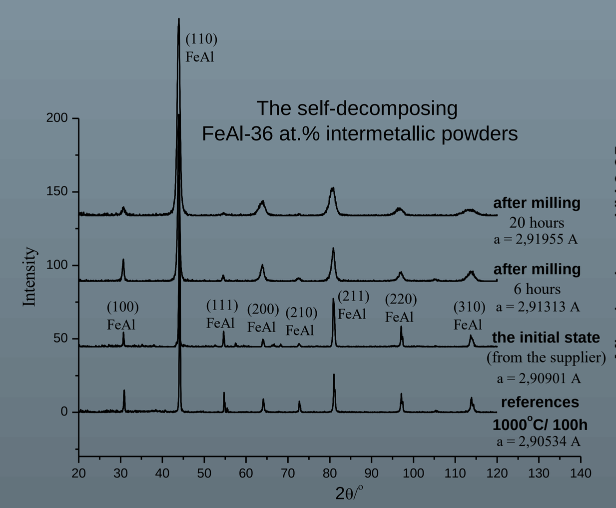


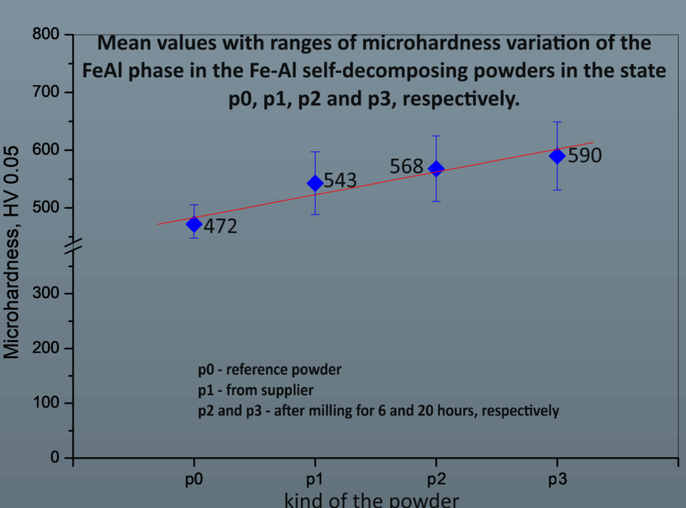
D-gun spraying „PERUN-S"

FeAl (DGS) coating

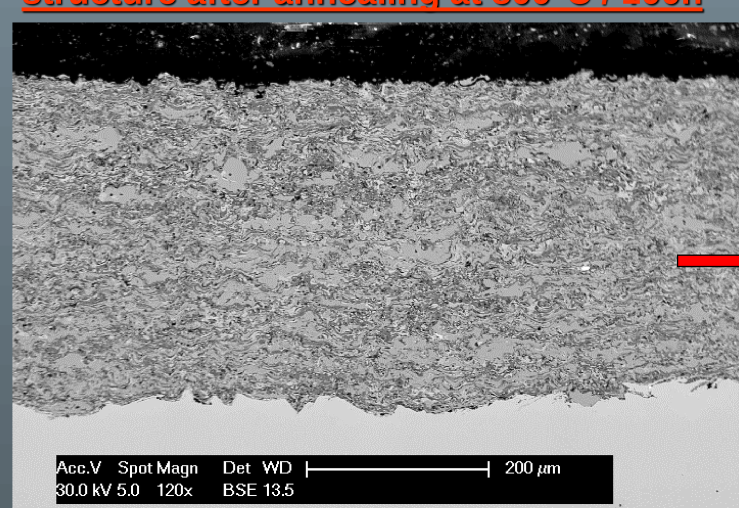


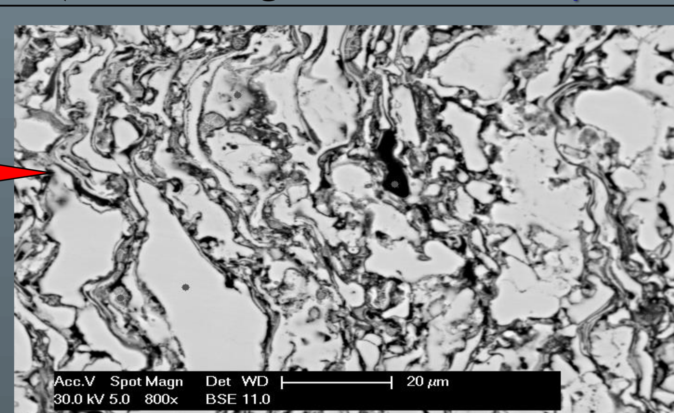






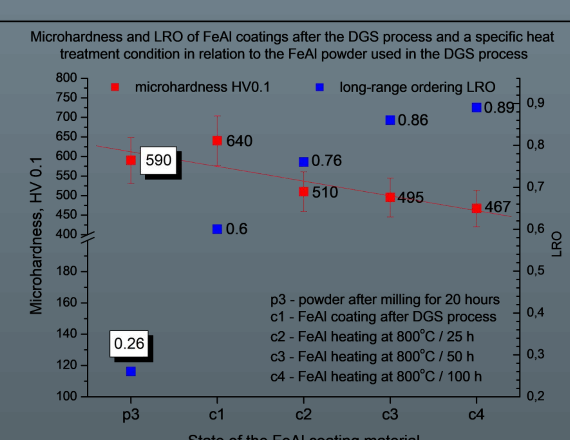
Homogenisation of the FeAl coating structure after annealing at 800°C / 100h

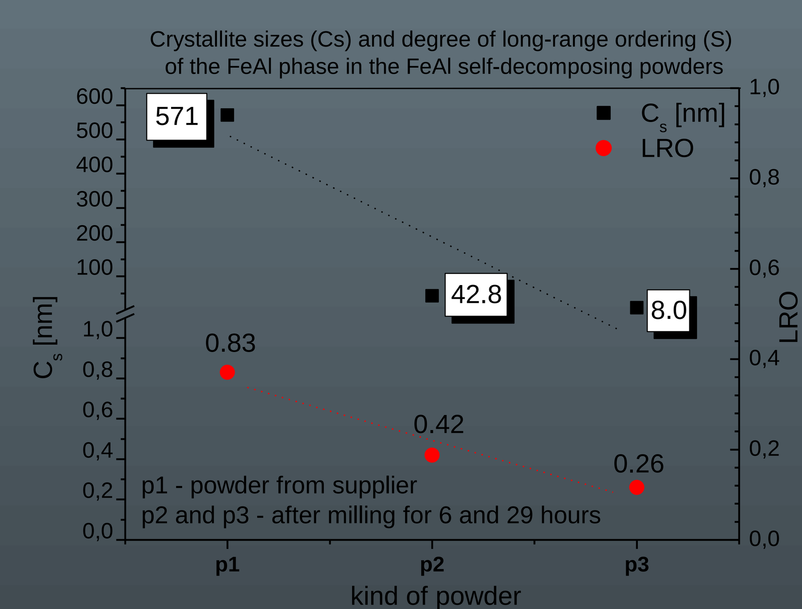




Materials and methodology

- Self-decomposing FeAl powder / D-gun sprayed FeAl coating — Material and technology — 15 HM boiler steel
- Initial state
- Heating at 800ºC in argon: 25 hours, 50 hours, 100 hours
- Methodology:
  - XRD phase analysis
  - longe-range ordering (LRO)
  - microhardness
  - Vickers hardness
  - Structural analysis:
    - SEM/EDS (*morphology, porosity, chemical composition*) and TEM microanalysis
    - surface roughness
  - Tribological wear:
    - using loose *abrasive wear* (quartz sand - PN-76/M-59115) between a rubber counter-sample rotating at 600 rpm at the load of 43 N for 10 minutes before the sample wear measurement
    - friction (*pin-on-disc*) test with a sliding speed (0.11 m/s on a 1000 m distance at a load of 20 N) between a 40 mm diameter cast iron ring and a 10 mm diameter FeAl coating sample (surface roughness above 1.5 μm Ra)





CONCLUSIONS

- *using FeAl self-decomposing powder, DGS technology makes it possible to produce Fe-Al coatings with a nanocrystalline structure containing Al_2O_3 oxide phases formed along grain boundaries, creating a like composite resistant to high temperatures;*
- *the produced coatings are structurally stable after annealing at 800°C for 100 hours, with a slight decrease in the hardness of the intermetallic matrix, compensated by the presence of oxide ceramics and the ordering structure of the FeAl (B2) phase;*
- *extending the preheating time at 800°C reduces coating wear while increasing the uniformity and degree of ordered structure of the FeAl coating, which retains a high hardness level (in the order of 600 HV 0.1 even after 100 hours of preheating);*
- *due to the heating time increases, the long-range ordering of the structure increases to approximately 76%, compared to the LRO of the reference material (consisting of FeAl-40%at powder heated in an argon atmosphere at 1000ºC for 100 hours and cooled in the furnace at a rate of 2ºC/min).*

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5th INTERNATIONAL CONFERENCE ON MATERIALS DESIGN AND APPLICATIONS - MDA 2024, PORTO – PORTUGAL
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