intellegens

# CASE STUDY

## Hardfacing welding consumables with Welding Alloys Group


## Executive summary

Wear is one of the most challenging problems faced by heavy industry. In mining alone, 17% of the consumed energy is used to combat wear failure, accounting for 2.7% of global $CO_2$ emissions. One of the most common methods to combat wear is by welding highly alloyed consumables (hardfacing materials) onto the surfaces of components. These must meet stringent requirements on safety, cost, environmental impact, and performance. Wear performance is determined by a complex interaction of properties, therefore optimising cost/benefit for hardfacing materials is difficult. This case study describes the journey taken by Welding Alloys Group (WAG) and Intellegens in applying machine learning to this problem, which **resulted in the development of an improved hardfacing material with dramatic cost/benefit advantages, not only from a performance, but also from an environmental point of view**.

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## Challenge

Wear is a very complex phenomenon. The common conception that high hardness secures high wear-resistant properties is misleading. Optimum wear resistance is defined by a complex interaction of chemical and mechanical properties of every material involved in the application. These properties include composition, hardness, toughness, Young's modulus, grain size, and phase composition. External parameters such as temperature, pressure, and humidity also play important roles.

In addition, random and/or systematic variations on wires and hardfacing welding procedures result in finished products with large discrepancies in performance. Environmental costs due to excessive use of highly polluting Chromium (Cr) are also a big concern, as well as the increasingly strict environmental regulations that push for lean welding consumables.

The goal of this project was to take one high-Cr cast iron-based welding consumable and to optimise cost/benefit as a function of chemical composition, based on abrasion-resistant standard methods as a performance metric, using the Alchemite™ machine learning toolkit.

## Solution

Alchemite™ is Intellegens' unique deep learning tool, which uses the power of deep neural networks to build comprehensive models across multiple compositions and material properties from sparse experimental data. The model for hardfacing materials was constructed with composition and physical property data from the literature as well as historical data from WAG. Weight loss was used as a measure of resistance to wear.

## Methodology

Stage 1: Model building and preliminary material design
Alchemite™ defined the most influential parameters in performance and suggested the first round of theoretical compositions. WAG engineers confirmed and approved manufacturing.

Stage 2: Validation
Formulations were manufactured, tested and validated against predicted values, showing acceptable agreement and falling within the calculated uncertainty.

Stage 3: Refinement
Additional iterations were carried out allowing the model to be refined.

Stage 4: Conclusion of modelling and laboratory work
A new formulation was defined. Laboratory tests showed comparable performance to existing products, but with a reduction of alloying elements by up to 50%, and price reduction of between 10% and 15%.

## Key outcomes

- **Predictions were experimentally validated.** The compositions selected for validation differed considerably from existing materials. Data on these new materials significantly improved the model.
- Alchemite™ proposed an **improved, more cost-efficient and environmentally- friendly alternative** to today's hardfacing material.
- WAG has taken this material forward to **industrial-scale performance trials**.

"The combination of extensive technical know-how and experimental data provided by WAG, and the unique deep learning algorithms provided by Intellegens, resulted in an improved material with drastic cost/benefit advantages."

*Jean-Marie Bonnel (Technical Director, WAG) and Mario Cordero (Innovation, R&D Manager, WAG)*

## References

[1] Global energy consumption due to friction and wear in the mining industry. Tribology International. Volume 115, November 2017, Pages 116-139

## Future opportunities

This outcome represents a significant step forward for Welding Alloys Group. It has shown a successful approach to using state of the art computational methods for the improvement of existing, and design of new, welding consumables. This approach is continuing for other ranges of welding consumables.

## About Welding Alloys Group

**Welding Alloys Group** is the go-to provider for advanced welding consumables, automated equipment for wear protection, and engineered wear solutions. Welding Alloys Group is committed to forming close customer relationships and has established numerous industry partnerships as a total solution supplier - from consumables and machines to integrated engineering solutions.

## About Intellegens

**Intellegens** has developed a unique deep learning engine, Alchemite™ for training neural networks from the sparse and noisy data typical of real-world science and business challenges. The technique was first developed at the University of Cambridge where it has been used to develop aerospace alloys, guide the design of new drugs, and design next-generation battery technology. The tool is now being used to solve a wide range of industrial customer problems, optimising products and processes, saving time and cost in discovery and development, and enabling breakthrough insights.

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