Vertical roller mills (VRM) have been a preferred method of grinding raw materials in the cement industry for many years and are one of the most cost-effective pieces of grinding equipment. All types of VRM rely heavily on the wear components to produce the highest throughput at the lowest possible cost. Welding Alloys Group has been actively involved in the cement industry for more than 30 years. By working closely with original equipment manufacturers, cement plant operators, its has become familiar with the challenges of this industry and has built up an extensive knowledge on vertical mill performance. Here it describes its Smart Welding Concept for VRMs.

The challenge of mill efficiency is to establish optimum grinding conditions with the correct level of production throughput in the shortest possible time to ensure the lowest production cost per tonne. By incorporating selected consumables, equipment, material knowledge and know-how, Welding Alloys has been able to develop a Smart Welding Concept that does not just refer to welding as a practice, but methodically looks at mill refurbishment as a whole, from the initial wear audit through to the management of the wear life during the cement production phase ultimately increase plant availability and lowering costs.

Casting versus welding

Looking at the rheological properties of the product to be ground, in particular its sliding resistance before passing between the grinding components, the efficiency is enhanced by having welded hardfaced surfaces. Contrary to cast parts, welded hardfaced surfaces are not smooth, meaning that the feedstock bed is conveyed more slowly as it is retained by adhesion to the rough welded surfaces, while moving under the grinders.

These rough surfaces offer an advantage that is often overlooked, but has fundamental importance. The slower movement of the material passing under the grinders considerably improves grinding efficiency. Due to this slower movement, the material spends more time in the grinding zone and makes the feedstock bed more controllable. This increased quantity of material under the grinders significantly increases output and reduces the recirculation rate.

The final particle size is reached quicker and more easily thanks to an autogeneous grinding effect that causes the product to interact with itself because of the formation of agglomerate that becomes more compact underneath the grinding components. Non-welded cast parts are subjected to abrasive wear, whereby they become extremely smooth with a very shiny appearance. These smooth surfaces tend to slip on the feedstock without achieving a proper grinding mechanism. While designers and foundries have tried all kinds of surface finishes to increase the material grip the grinding components have on the feedstock, cast surfaces still don’t offer the same grading performance as welded surfaces.

The phenomenon of wear is not constant across the width of the rolling track. The outer work area is subjected to the greatest mineral aggression. In this area, the particles are the finest and consequently greater in number per unit of volume. Furthermore, due to the centrifugal effect, their speed is the highest in this part. Consequently this area has the most exposure to wear in VRMs. Another advantage is that hardfacing offers the possibility of applying different materials with varying wear properties in different areas, to optimally adjust the grinding efficiency and rate of wear. This technique has been used by the Welding Alloys Group with great success.

The Smart Welding Concept

1. Analysis of operating conditions: One of the first steps in improving wear life of any component is to gather information with regards to the current condition of the equipment, the environment in which it operates, the type of media being ground and the required and actual throughput. By carrying out the initial wear audit and mill inspection, groups like Welding Alloys Group can propose diagnostic assistance and a support service to reduce the running cost of a VRM. This will consist of the initial wear audit, identification of areas that need rectifying and offering the correct, technologically-advanced welding consumables, technical know-how and welding techniques and equipment to reduce operating costs and increase reliability.

The aim is to reduce energy consumption per tonne milled, while seeking higher productivity over longer periods of time. VRMs are increasingly being used in the cement industry due to their energy efficiency. It is not unusual to find different VRMs for grinding raw material and cement on the same site and they are also used for pet coke, coal and blast furnace slag.
2. Hardfacing intervals and the influence of Smart Welding: The smart and methodical management of profiles can optimise the maintenance of VRMs. The solution lies in not letting the profiles deteriorate to the point of aggravated wear. Figure 1 shows the evolution over time of equipment performance that is subjected to in-service wear.

Wear of components results in both lower productivity and higher energy consumption as the amount of wear increases. Figure 1 shows that the quicker a mill can pass through Period 1 to reach the optimum grinding phase Period 2, the more efficient it becomes and longer it will operate under these optimum conditions, lowering the operating cost per tonne. Through proper mill management, the grinding components are refurbished as soon as possible after entering Period 3. This eliminates excessive wear, increases productivity, prevents an increase in cost per ton and reduces the time that service teams have to spend on site. It has also to be noted that Period 1 may be reduced by optimising the original table and roller profile. This is easily achieved by adapting the welding bead sequences.

By analysing the localised wear of the grinding components it is possible to select the appropriate welding consumable alloys that will actively contribute to combatting the phenomenon of the localised wear. This will ensure that the grinding profiles stay close to the original profile, enabling the producer to maintain an optimum process that is stable while functioning at a constant productivity for longer periods of time. (See Figures 1 & 2). The imperceptible effect of wear will delay the appearance of a degraded mode of operation. This stable operating mode must be maintained over longer periods of time. With this configuration, the results are most favourable: Higher productivity; Lower energy consumption; Lower cost per tonne milled.

It is important to understand how to control and minimise wear from start-up and not to allow aggravated and localised wear to set in. In keeping this approach, hard-facing should be carried out as soon as wear is detected (entering Period 3) rather than planning for a major hard-facing operation or be obliged to replace the worn parts. The Smart Welding concept offers optimal performance while reducing running costs of installations. Experience from the Welding Alloys Group suggests that this objective could be achieved with maintenance performed every four months (See Figure 3).

3. Specific aspects of Smart Welding for VRM maintenance: The specific nature of hardfacing alloys offers exceptional characteristics to increase resistance to abrasive wear. Abrasion is a phenomenon that is specific to wear of materials (See Figure 4). It depends on the size, texture, mass, speed and angle of approach to the substrate of the particle, the medium in which it is transported as well as temperature and phase (liquid, solid or gas). The consequence is a loss of material on the surface of the substrate.

In order to resist abrasive wear, a ductile base body combined with finely dispersed hard particles makes it possible to increase the wear resistance of materials, in this case in VRM rollers and tables. During
welding, the rapid cooling rates result in the formation of very hard and fine primary carbides within the structure. Only welding offers this physical property. In comparison, for the same material grade, cast parts do not produce carbide structures of such a high density. By means of welding, the high-density primary carbides can be introduced into a tougher and more ductile matrix. It is mainly these primary carbides contained in the matrix of the weld deposit that constitute the key feature of performance with relation to abrasion resistance. The primary Cr23C6 carbides in this case have a typical section of less than 50µm. These carbides offer hardness in excess of 1000 on the Vickers hardness scale. The harder and finer these carbides are, the better the wear resistance of the material. The principle of wear resistance using these carbides on the material surface is explained in Figure 5.

An optimal dispersion of hard carbides in a ductile matrix will result in a reduction in the size of the metal shavings removed by the action of abrasive particles. In comparison, a cast metal structure will present coarser and fewer carbides. By making use of the flux-cored arc welding process, The Welding Alloys Group produces consumables with optimised chemistry that are perfectly suited to the needs of cement manufacturers. Figure 6 presents diverse as-welded structures for four distinct flux-cored hardfacing wires in the company’s product range.

4. Alloys used in weld deposits:

The size and distribution of carbides varies from one product to another depending on the alloying elements used. Moreover, it must be noted that, depending on the alloying elements selected, the hardness of the primary carbides varies from 1350 for a chromium carbide up to 2900 for a vanadium carbide as measured on the Vickers hardness scale.

Industry has developed reproducible and calibrated testing methods to categorise different materials and alloys according to their resistance to abrasive wear: The wear rate index of materials measured in the laboratory by the test method as described by the ASTM G65-A test standard, rates different material according to their ability to withstand fine, dry particle abrasion.

The principle of the ASTM G65-A test is based on measuring the loss of mass of a sample subjected to pure abrasion by a moving mineral compound under a constant load. Figure 7 presents comparative results of weight loss of various materials tested ac-
cording to the ASTM G 65-A test. As can be seen, the MILL 600 sample for example had the lowest weight loss.

Figure 7 compares the maintenance costs between using the Smart Welding hardfacing solution and a conventional solution of replacing grinding rollers. Literally thousands of VRM wear parts have been successively hardfaced, some up to 15 times, without any damage using this approach.

This work can be carried out in-situ or in one of Welding Alloys Group’s fully-equipped Integra workshops strategically situated around the globe. We have components that were manufactured in the early 1990’s that are still operational today. This clearly indicates the efficient long-term strategy for roller mill maintenance. The trend over the past few years has been in favour of on-site hard facing maintenance directly on the roller mill without any need for disassembling. Figure 9 illustrates in-situ welding of VRMs and supply of spare parts.

**Summary**

The Smart Welding Concept reduces running costs, reduces handling costs, proposes a flexible and customised maintenance solution to fit specific needs, reduces replacement costs, proposes environmentally friendly solutions, ensures reliability of equipment performance over a long period, reduces storage costs and optimises total cost of ownership. Welding Alloys is also capable of repairing damaged VRMs on site. All of these advantages are possible through a proper wear audit to analyse all aspects of the mill.

Furthermore, even if alternative technologies such as ceramic could sometimes provide better durability of roller mill components, the Smart Welding Concept offers the additional advantage of extending the service life of profiles and reducing the operational costs of vertical mills in the long term. Lastly, it is important to note that the Smart Welding solution does not involve any heavy maintenance requirements and thus greatly minimises the risk of accidents.