APPLICATIONS FOR COMPOSITE MATERIALS IN THE MINING AND METALLURGY INDUSTRY, PRESENT AND FUTURE

Z J de BEER

AERODYNE TECHNOLOGY

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By ZJ de Beer, Hons.B Eng (Stellenbosch)

INTRODUCTION

Composite materials are normally advertised as "New" or "Revolutionary". This strategy does not serve the purposes of the industry well. In fact composites are well known materials and have been around for centuries. In the present modern form, GRP composites are at least 50 years old. The materials have a long and mostly successful history in wide ranging applications.

As an industrial material, composites are mainly used for their excellent resistance to chemicals and most forms of corrosion. This property, although traditionally important, is hardly the only useful property. Other very useful properties are :

- Low mass
- Low cost
- Unique manufacturing and processing possibilities.
- "Tailor made" properties.
- Complex shapes are easily made.
- Low tooling costs.
- Applicable to very large and small products.
- Good surface finish can be a built-in feature.

This paper deals with the applications of GRP composites in the SA Mining Industry as well as some found in the United States. New applications that could be considered in South Africa are explored in some detail.

PRESENT APPLICATIONS IN THE USA

The uses of composite materials in the South African mining and metallurgy industry are not well documented but the following uses are known to the author:

- Chemical resistant piping and tanks for platinum refining.

- Insulation cladding for chilled water transport.

- Ventilation ducting.

The uses of composites are well documented in the USA and the following lists the more common uses of the material:

- The coal mining industry makes extensive use of GRP composite pipes for fresh water, acid water and slurries. GRP replaced mild steel and wood incapable of handling corrosion associated with sulfuric acid. Successful installations can be found at Eastern Associated Coal, Consolidated Coal, North American Coal, Carbon Fuel and many others.

- Bottom ash is transported by a Texas coal burning electrical utility. The ash is composed of 12% iron oxide, 40% silica, 16% alumina, 22% calcium, 2% magnesium 1% sodium and traces of other metals. The useful life of the piping is 1-2 years longer than cast iron and installation was significantly cheaper.

  Philip Sporn Plan Central Operating Co. of West Virginia pump fly ash at a 10% ash concentration. They estimate that the pipeline has an indefinite life at this concentration.

- The Hodge-Union Texas project in Oklahoma is considered the largest GRP Epoxy installation in the world. Approximately 150 000 m of pipe was installed. The pipe was selected due to high resistance to corrosion and paraffin build-up.

- A paper mill in Wisconsin uses 800 m of GRP pipe in a waste water treatment plant. The 316 stainless steel pipes used previously could not endure the sodium hydroxide corrosion.

- GRP ducting and pumps are widely used in corrosive applications in the USA.

POTENTIAL APPLICATIONS IN SOUTH AFRICA

Some of the potential applications that are under consideration or in use in the SA industry include:

- Low mass mine props of various types.
- Piping for chilled water will need much less insulation or even none in some cases.
- Low mass skips and hoisting ropes.
- Low mass and high capacity breathing apparatus cylinders for fire fighting.
- Corrosion resistant air handling equipment.
- Slurry transport.
- Ventilation ducting.
- Thermal insulation cladding.
- Hydro power piping.
- Corrosive fluid handling and storage.
- Corrosion resistant cable trays and gratings.
- Blast protection.
- Water hydraulics.
- Air actuators.

Mine Props

Mine props attract much attention from alternative materials since the standard steel prop is ill equipped to survive the corrosive underground world. But the steel prop has some very attractive features :

Low initial cost.
Proven blast resistance.
Mechanical durability.

The negative characteristics are:

Poor corrosion resistance.
High mass to be overcome by the worker which reduces productivity.

Various parties have investigated the possibility of developing a composite prop. To date we are not aware of any successful attempt in this field. The size of this potential market is big enough that we can be sure that more attempts will be made.

Chilled Water Transport

The use of chilled water in mining has spawned a host of suppliers of insulation systems for steel piping. The universal difficulty is the requirements for low cost and fire resistance.

The return to use of thermoplastic(uPVC, PE etc.) piping would to a large degree solve the cost problem but this system is totally unacceptable in terms of the fire risk.

An alternative approach would be to develop a thermoset phenolic pipe with inherent fire resistance and a high insulation value. This type of pipe could possibly be used without any extra thermal insulation. The major restraint on this type of development would be to ensure that the new system is compatable with existing piping and the current mine practices for installation.

The advantages of the new system are :

- Insulation is no longer required (as well as the extra work to clad the piping).

- The piping would be inherently corrosion resistant.

- The piping would have a low mass and would be easily installed and transported underground.

- The piping would have a smaller cross section and thus need less installation space.

- The piping would have inherently low pumping losses due to the excellent inside surface finish.

High Pressure Piping for Hydro Power

A composite pipe could be suitable for the transport of high pressure water in the Hydro power field. The inherent corrosion resistance of the material can be a very attractive feature if untreated mine water is used as an energy source.

The corrosion performance of the pipe would outperform stainless steel in most if not all cases. On the other hand the development of such a system would require work in joints and other fittings. The design of the pipes would not conform to existing specifications and research will also be required here.

Corrosive & Chemical Fluid Handling

Although this application is known in South Africa it is mentioned here since there seems to be much more scope in this very good application of composite materials.

The resistance of composites to almost any chemical attack in virtually any form makes this application the one where the materials should have no competition. The local GRP industry has not always managed to profit from this fact. On the other hand the substitution materials have generally failed dismally.

The successful application of composites in this field depends on the co-operation between the manufacturer of the resin system and the specifier or client. The choice of the resin system has a fundamental impact on the long term performance of the system. The huge choice of candidate complicates the matter but is in fact the solution.

Water Hydraulics

The application of composite materials to water hydraulics equipment is technologically feasible at the moment. The advantage of a composite hydraulic cylinder would be low mass and the high resistance to corrosion from untreated water..

Again the main question concerns the cost effectiveness of this solution. The lower mass of the composite cylinders would have some indirect advantages to the user.

The main aspect that we would have to address is the wear resistance of a composite cylinder if the water contains abrasive particles. The solution to this problem would be some wear resistant liner material such as a ceramic reinforced resin. The work done on slurry piping could be useful in this case as well.

The remaining problem with a GRP or composite pipe is the fire - resistance aspect. This could be solved with Phenolic GRP. Unfortunately the chemical resistance of Phenolic GRP is not up to the standards set by other resin systems such as Epoxy and Vinyl Ester.

Slurry Transport

This application has been successful in the USA and should be a relatively easy task to implement locally. Again the basic technological requirements can be met by our own industry.

Time will however have to be spent to find the most suitable solutions to our unique requirements.

Skips

The own mass (deadweight) of an empty skip directly affects the performance of the primary transport system in a mine. Reducing the mass of the skip allows us to extend the working depth of a hoist and reduces the power requirements thus saving energy or increasing productivity due to the increased hoisting speed.

Fundamentally there is no reason why a composite material skip cage could not be developed. In fact this development is probably the most straight forward of all the potential applications of composite materials in mining.

All the technical pre-requisites for the development are in place in South Africa at the moment and the only question that we have to answer is if this application would have a better life cycle cost than the current metal systems.

The advantages of a composite material skip is not confined to the increased productivity. Other advantages that can be identified are:

- Increased payload or higher safety factors.

- Lower maintenace as a result of corrosion resistance and less wear on hoists and cables due to mass savings.

- Increased working depths.

We could expect the composite skip to be less than 40% of the mass of a conventional steel skip.

Low Mass Breathing Apparatus

Composites are well known in the construction of low mass Breathing Apparatus Cylinders (BA) in the USA. The important advantages of composite BA are:

Higher storage capacity for the same mass.

Non-catastrophic failure.

Non corrosive material.

Fire resistance.

This application is one of the more sophisticated and would require in-depth analysis and development. The fundamental technology is available and we foresee no special difficulty in this development.

The Perpetual Problems of GRP Composites

Although composites have been around for a relatively long time one cannot claim that the material has been universally successful. The reasons for this can be found in many aspects of the materials themselves as well as the industry.

Structural Design

Although a GRP composite can be very simple to work with, the **design of products or structures with GRP is not a simple task.** The structural design of a composite material product is an order of magnitude more difficult than design with conventional materials. In fact successful design can only be made with the aid of advanced computer methods.

The common use of standards, e.g. BS and Loyds does not completely safeguard the end user against unexpected failures in use. The standards also create the impression that a design has been done. Worse even, the standards oversimplify the problem and allow completely unqualified persons to **"Design"** with GRP.

Specialists are required for the design of GRP composite products and in fact are available in South Africa. Unfortunately they are not well known and used even less.

The structural design aspect of a composite material product should not be neglected and is the last place to try to save costs. Intelligent design eventually saves much more than the cost the specialist charges for his services.

Chemical Qualification

Similarly neglected in the design process is the choice of the resin system which is the major contributing factor to corrosion resistance. Depending on the application the chemical resistance of the candidate resin systems should be qualified for the specific end use.

The resin manufacturer must be involved in the chemical design of the product. Most of these companies will assist in this matter to protect their own interests. Most often, time constraints will relegate the qualification to a short term test which is not in the interest of good design practice. It is important to know that short term tests are not always sufficient to establish the suitability of a resin system for a specific purpose.

Material qualification is not required in many cases since the resin manufacturers have established valuable empirical corrosion data. The information is available but care must be taken to ensure that the chemical analysis of the corrosive medium is established accurately and completely before selecting a resin system.

Care should also be taken in accepting the validity of the data since resin manufacturers change the formulations of their products over the years. Small differences in curing agents can also affect the validity of data.

Manufacturing Standards

The best designed GRP composite products will fail dismally if the manufacturer is not capable of producing the article in the correct manner. The apparent ease of use of the material and the small entry barriers to the industry have allowed many untrained persons to participate in producing below standard products.

The average GRP shop might be perfectly capable of producing a wide variety of articles very successfully as long as the true potential mechanical and chemical properties of the materials are not required.

One must not consider the manufacture of a GRP waste paper container on the same level as chemical plant equipment. If buyers perpetually insist on purchasing the lowest cost products future performance will reflect this decision. The powerful low cost features of the material are in fact spoiling it's reputation.

Manufacturing Processes

Only a few local GRP manufacturers employ processes other than **Hand Lamination** which really should not be called a manufacturing process at all. The wide adaptability hand lamination is the most abused aspect of the entire GRP industry. The process allows very little control of properties, mass and cost.

If the local industry persists in this wholesale abuse of the material the the industry will remain static and even regress as other materials make inroads into established GRP domain.

The established "Advanced Processes " must be implemented more widely before the prospects of the industry will change for the better.

The following processes are successful elsewhere or on a small scale locally:

Pultrusion.

Pullforming.

Press molding (SMC, BMC, low pressure).

Resin Transfer Molding.

Filament Winding.

The key in selecting a suitable process for GRP manufacture is to find the lowest cost method which will guarantee the minimum required quality of the product.

Conclusion

GRP Composites can play a much more significant role in the local mining industry. The true potential of the material will however only be achieved if the GRP industry is willing to take risks, innovate and invest in technology and equipment. Fortunately much of the required technology is available locally at present.

Likewise the mining industry shall have to participate by sharing risks and investing in this very exciting technology.

Lastly it is important to realize that the development of new products for the mining industry will require very close ties with the GRP industry. It would be virtually impossible to develop successful products on our own.