CERAMIC ARMOR WILL BE REPLACED BY COMPOSITE ARMOR VERY SOON*

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ABSTRACT. *Ceramic armors have existed for more than 30 years. They replaced the much heavier metal armor.One of the biggest producers of ceramic armor is Bittosi in Spain. It is a confidential product with no open promotion. Ceramic armor is the side products of Bitossi. Their main products are alubit liming and balls for ceramic industry, paint and pharmacy. Their ceramic armors have been used by many countries in Europe and by NATO. Actually, ceramic armor is still too heavy for soldiers since itweighs approximately 8.6 kg depending on size, and is still too rigid. Therefore, people are still looking for more convenientmaterials, which is resistant to shooting, flexible, and lighter.*
The answer is composite productdeveloped by De Staat Mijn-DSM Research Campus Geleen of the Netherlands, specialist in polymer research. They have proved it very successfully in shooting test. It is flexible and weighs only about one third of ceramic armor. The composite is produced from 20 layers of 0.15 mm thickPE (Poly Ethylene) sheets,reinforced by carbon fibers. Since it is far better than ceramic armor, the composite armor will replace ceramic armor very soon. It is only a matter of time.

Keywords:ceramic armor, composite

INTRODUCTION

Alubit is a brand name for high alumina ceramic product produced by Bitossi. Bitossi is a big ceramic company in Spain, a member of Collorobbia Group. Itsmain productsare alubit lining and balls for grinding of ceramic body, glaze, paint and others. Alubit mozaic for ceramic armor is only their side product. They produce thousands tons per year and sold them to ceramic and paint industry all over the world. Alubit is a leading product in the market due to their quality and availability. It has been in the market since more than 30 years ago.

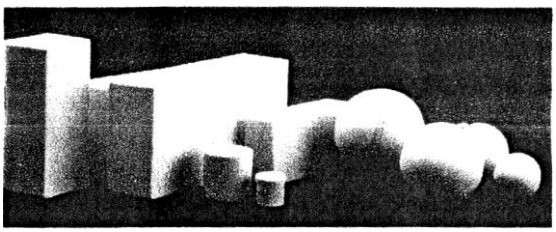

Figure 1. Alubit and other Bitossi'sproducts

Alubit is a ceramic material, which has excellent technical spesification. It is very hard, strong, not brittle and it has avery high tensile strength, bending strength, impact strenght and compressive strength. Therefore, alubit mozaic have been proven to resist shooting. That is why alubit is used for the construction of ceramic armor.

PREPARATION OF CERAMIC ARMOR

Body composition of alubit is as follows: 97% alumina, and 3% kaolin or white burning-clay. A small quantity of CMC or Arabic gum as binder is added to the body powder before pressing.

Body Grinding

Alumina, clay and water are ground in a ball mill using alubit lining and balls into a very fine texture where above 90% of particles we` re finer than 2 micron. The grain size is determined by SEDIGRAPH laboratory equipment. It needs a very long grinding time to reach the necessary fineness. Such fineness is needed to reduce the firing temperature.

Powder Preparation

The ceramic body slip was turned into powder by spray dryer. Since the body powder is very poor in plasticity due to small quantity of clay, CMC or Arabic gum should be added in small quantity. The

powder was then ready to be pressed.

Forming

Trapezoidal alubit lining can be pressed normally, but alubit balls need isostatic pressing using double rubber mould and hydraulic oil to ensure similar strength of all parts. Alubit mozaic is formed by normally pressing two fine holes in each side. Ceramic armorscombinemany alubit mozaics.

Firing

Firing of the products is done in small tunnel kiln by using saggar. The firing cycle is very exceptional. Most of the firing curve is used for soaking time. Total firing cycle is 60 hours: Pre-heating 10 h, Soaking time40 h, Cooling10 h.

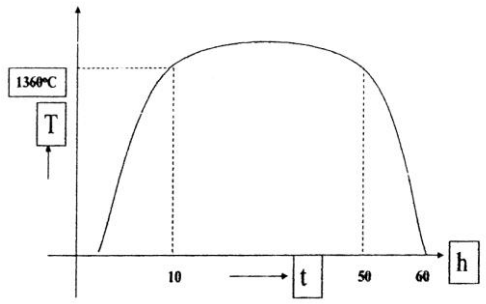

Figure 2. Firing Cycle

Technical Spesification

The technical spesification of alubit product including the ceramic armor are as follows:

Table 1. Technical Specification of Ceramic Armor

Technical Specification	Units	Alubit Product/Ceramic Armor
1. Al_2O_3 content	%	97
2. Spesific gravity	g/cm^3	3,7
3. Porosity	%	-
4. Hardness: - Moh's - Rockwell	- R45N	9 75-79
5. Compressive strength	kp/cm	22,000
6. Bending strenght	kp/cm^2	3,400
7. Elasticity modulus	kp/cm^2	2.8×10^6
8. Impact strength	$kpcm/cm^2$	8
9. Colour	-	White

Construction of Ceramic Armor

Ceramic armor is constructed by many alubit mozaic, connected by metallic wire. The size of alubit mozaics are 38 x 38 x 4 mm. It is then covered by fabric and sewn. The armor should suit to the body of the soldier. Therefore, there are some sizes available. Ceramic armors are normally used as jackets, put on outside the clothes of the soldier. Ceramic armor only protects the main body of the soldier. A ceramic armor weighs about 8.6 kg depending on its size.

Disadvantages

Ceramic armor should be replaced by composite armor because of the following reasons:

- Too heavy: making the soldier feel inconvenient.
- Too rigid: making the soldier not so flexible in movement.
- Only cover the main body: only protect part of the soldier body.

COMPOSITE ARMOR

Composite armor consist of several layers of very thin composite sheet with total thickness of about 3 mm. The composite sheets are carbon fibre-reinforced thin polyethylene sheets (CRPE). CRPE Composite is a strong and good material, yetflexible.Therefore thecomposite armor is strong, light and flexible, so it is more convenient for the soldier. Composite armor is developed by DSM Research Campus Geleen of the Netherlands. It has been tested for shooting resistance with good result and is only 2.9 kgin weight.

CRPEComposite

CRPE compositesconsist of carbon fibres as reinforcement and polyethylene as matrix or bonding material. This material has a very good mechanical strength, bending strength, tensile strength and impact strength. It can be produced in a very thin sheet of 0.15 mm (150 micron), yet still hasa good stregth and is flexible (not rigid).

Technical Spesification

The CRPE has a very good mechanical strength as follows:

Specific gravity :1.76kg/cm^3
Flexural : 218,200 lb_f/in^2
Tensile modulus :21 x 10^6 lb_f/in^2
Compressive strength :143,900 lb_f/in^2
Compressive modulus :26 x 10^6 lb_f/in^2

Table 2. Comparison Between Ceramic Armor And Compposite Armor

	Properties	Ceramic Armor	Composite Armor
1	Basic material used	Ceramic	Composite CRPE
2	s.g in gr/cm^3	3.70	1.76
3	Hardness Mohs scale Rockwell	 9 78	 - -
4	Rigid/flexible	Rigid	Flexible
5	Weight, kgs	8.6	2.9
6	Thicknesss, mm	4	3
7	Protection	Main body only	Main body and lower body (short pants)
8	Usage	Outside cloth	Outside or inside
9	Convenient	Less convenient	More convenient
10	Strength	Strong enough	Strong enough
11	Shooting test result	Good	Good

The Construction of Composite Armor

Composite armor consists of 20 layers CRPE of 0.150 mm thick each. The layers are combined by heat in many points or lines. Then it was cut into an armor design.

Advantages

There are some advantagesin using composite armor:

1. Very light, only 2.9 kgs or about one third of ceramic armor weight.
2. Flexible and not rigid like ceramic armor.
3. Can be used either outside or inside of the soldier clothing.
4. Because it is very light, it can protect the lower part of the body and used as short pants.
5. More convenient to be used.

Inventor Profile

DSM Research Campus Geleen in Netherlandsinvented the composite armor. Italso develops the carbon fibres composite for the usage in aircraft, aerospace and automotive. Another product is imitation grass. It is formerlythe State Coal Mine. After the coal mine was closed, the activity wastransformed into polymer research campus. The progress of the research campus is very fast and so advanced. Thanks to the finding of the micro laboratory equipment, which drive the research progress very fast.

The micro laboratory equipment can be used for testing with only 5-15 grams of raw material. There are 4 micro laboratory equipments: micro extruder, micro injection moulders, micro cast – film device, and micro fibre spinning.

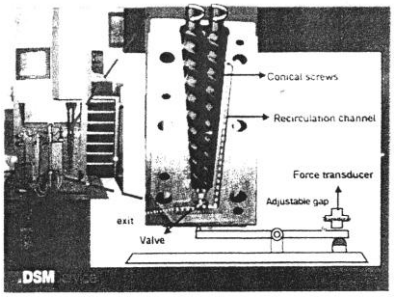

Figure 3. Internal Design of Micro-Extruder

CONCLUSION

Since there are many advantages of composite armor compared to ceramic armor, CRPE composite armor will be the future armor. It is strong, light, more convenient and able to protect more parts of the body. Ceramic armor will be no longer in the market and will be replaced by composite armor very soon. It is only a matter of time.

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