INVESTIGATION ON BALLISTIC PERFORMANCE OF NANO-STRUCTURAL GMA DEPOSITS OF ARMOR UNITS

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Introduction

An optimization of metal shields against projectile impact has been long of practical interest in military and civilian applications [1]. Armor or ballistic resistant materials directed at defeating armor piercing projectiles are generally selected for hardness and steel is basic armor material [1]. However, steel is not suitable to be used as a lightweight armor since it has a relatively high density and low ballistic impact behavior in comparison to ceramics or laminated composites [2]. Harder materials offer several advantages for defeating armor piercing projectiles: provide a greater resistance to penetration and will be able to blunt or flatten out the pointed tip of an armor piercing projectile. Blunting the pointed tip of a projectile will increase the impacting surface area of the projectile which will decrease the impacting stress applied by the projectile. Desirably, the armor material will also be tough enough so that it can provide multi-hit capability or protection. While ceramic armor materials are very hard and provide good armor piercing protection, due to the brittleness of the material, ceramics do not generally provide multi-hit capability. Typically, after an initial impact, the ceramic material will fracture or shatter.

Although a lot of investigations have been done on the perforation resistance of monolithic plates experimentally, numerically, and theoretically, limited studies on hardfaced metal armor shields were reported in the open literature [3]. The high density disadvantage of steel armor has directed our researches to investigate nanostructural steel to get armor units providing much higher ballistic impact behavior at the same weight as ARMOX 500 steel plate. This paper proposes a robotized GMA hardfacing of special armor units that structure consists of one austenitic buffering layer and a layer of nanostructural deposit covered by thermal arc sprayed layer, to provide very high improvement of ballistic performance over a monolithic single or double plate of ARMOX 500 steel. On the basis of a series of tests, authors found that nanostructural hardfaced armor units are much more effective in resisting perforation than monolithic plate HARDOX 500 12,0 [mm] thick of the same weight under projectile impact.

Experimental

Materials

To produce high quality deposits nonstructural wire FST W-685.1, produced by Flame Spraying Technologies was selected. Weld metal deposit is characterized by very high 70-72 HRC, corrosion resistance, impact and wear resistance. As the base metal S355J2G3 carbon steel plates 6,0 [mm] thick where selected. To compare ballistic impact tests results HARDOX 500 8,0 [mm] thick plate was used.

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Apparatus and procedure

Robotized GMA surfacing was performed on the stand equipped with REIS welding robot, TotalArc^2 5000 power source and FRONIUS wire feeder. Deposits were surfaced to study the influence of the heat input of GMA FST W-685.1 wire surfacing on the quality, shape and dilution and deposition rate of stringer and weave bead deposits. Ballistic tests where performed in accordance to STANAG TOP 2-2-713 (level III) on the experimental stand equipped with riffle Mosin wz.1891/1930, and bullets 7,62x54R mm.

Results and Discussion

To establish GMA hardfacing procedure of armor units, preliminary tests where done to study the influence of basic hardfacing parameters on the quality of stringer beads and weave beads deposits, surfaced by nanostructural FST W-685.1 metal cored wire 1,6 mm dia. Analysis of results indicated that the highest quality are provided by weave bead technique of surfacing. The highest quality and lowest dilution can be achieved for 3,5-4,0 [mm] thick weave bead deposits. Next experimental armor units were produced by robotized GMA hardfacing of base metal S355J2G3 carbon steel plates 300x300x6,0 [mm] of total thickness 9,5-10,0 [mm], Table 1. To keep on place nanostructural deposits break off pieces, due to bullet impact, additional soft aluminum layer 2,0-2,5 [mm] thick was thermal arc sprayed on clean surface of nanostructural deposit. Total thickness of armor units was about 12,0 [mm]. Ballistic tests indicated that nanostructural material hardfaced armor units provide very high ballistic impact resistance much higher then ARMOX 500 steel

Table 1 Robotized GMA FST W-685.1 metal cored wire 1,6 mm dia. weave beads hardfacing and automatic thermal arc spraying conditions of S355J2G3 steel plates 6,0 [mm] thick, to produce armor units.

Hardfacing technique	Bead geometry	GMA hardfacing and thermal arc spraying parameters
Buffering by GMA surfaced austenitic solid wire - 18-8(45554) ϕ 1,2mm overlap of weave beads - 20%	BW=18,1 mm, T=3,5 mm, P = 14,2 mm	**Arc** current - DC+ impuls, I = 160 [A], Arc voltage U = 22,0 [V], V= 2,0 [mm/s], Weave bead amplitude = 6,0 mm, frequency = 0,2 Hz Stick out = 20 [mm] progr. no 23, Shielding gas - Ar+2,5%CO_2, Q=18[l/min], interpass temp. < 100^{o}C, no preheating
GMA hardfacing of weave beads - overlap of beads - 20%	BW=20,6 mm, T=3,5 mm, P =16 mm	**Arc** current - DC+ impuls, I = 200 [A], Arc voltage U = 23,6 [V], V= 2,0 [mm/s], Weave bead amplitude = 6,0 mm, frequency = 0,2 Hz Stick out = 20 [mm] progr. no 49, Shielding gas - Ar+2,5%CO_2, Q=18[l/min], interpass temp. < 70^{o}C, no preheating
Automatic thermal arc spraying	T= 2,0-2,5 [mm]	**Arc** current - DC+, I = 115-120A, arc voltage - U = 32-34V, Air pressure = 5,0 bar, torch distance to the unit - 180-200 mm, preheating temp. 50-60 ^{0}C

Remarks: BW – bead width, T – bead thickness, P – pitch (bead center to overlapping bead center). Thermal arc spraying consumables: bonding layer: wire TAFA 75B Bond Arc – ϕ 1,6 mm (Ni+%5,0 Al) and external layer: wire - TAFA 01T ϕ 1,6 mm (100% Al)

A - penetrated

B – not penetrated

Fig. 1 A view of results of ballistic test of: a - ARMOX 500 steel plate 12,0 [mm] and b - Armor unit - 14G-PN AlNiAl – 12,0 [mm], in accordance to STANAG TOP 2-2-713 (level III) tests

12,0 [mm] thick, Fig. 1. Metallographic examinations of GMA nanostructural deposit and thermal arc sprayed layer proved high quality of armor units.

Conclusions

Comprehensive study of GMA hardfacing technology of nanostructural deposits provided technological background to use selected parameters to produce armor units characterized by very high ballistic performance in comparison to monolithic plate HARDOX 500 12,0 [mm] thick or two HARDOX 500 plates 6,0 [mm] thick. Results can be implemented in production of army infantry transportation vehicles, replacing less effective monolithic steel plates or very expensive ceramic or composite armor units.

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