Simulation of dynamic load of individual and collective protection elements elaborated from high entropy alloys

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Keywords

HEA, individual protection, collective protection, dynamic load

1. Introduction

The high entropy alloys of the AlCrFeCoNi class chosen for use in the present scientific research work have excellent properties of resistance to compression and corrosion. They were selected for the construction of complex composite structures of the type HEA-STEELS, HEA-PM, HEA-CM resistant to high deformation speeds, suitable for use in the field of collective and/or individual protection. The most widely used method for obtaining HEA is that of electric arc melting of the load materials in a vacuum arc re-melting installation (with current values up to 500 A), under controlled atmosphere [1-4, 6]. In order to obtain the high entropy alloys from the AlCrFeCoNi class, two working procedures have been developed:

- Working procedure for obtaining the Al0.8CrFeCoNi alloy in the RAF facility - MRF ABJ 900

- Duplex working procedure for obtaining the Al0.8CrFeCoNi alloy in the induction furnace BALZERS, HU-40-25-40-04 and in the RAV installation - MRF ABJ 900.

2. Design of the shape of protective element

The protection element supports a high value energy transfer, exceeding the flow limit upon receiving the specific large amount of energy being a continuous reality, regardless of the material used. Furthermore, the energy transfer between the protection element and the vehicle shield is also kept at a high value, the shielding occurring most often, again, regardless of the nature of the material of the protection element. For this reason, the design started with the solution of the impact energy absorption, so that the material of the protection element consumes as much of this energy as possible, and the volume of energy transferred to the shield is reduced to non-dangerous values for the integrity of the latter.The protection element can consume a good amount of energy by deforming, a modification that does not significantly affect its functioning during a combat action. Assuring by design the possibility of elastic and plastic deformation of the material of the protection element, a good part of the impact energy received is consumed in this regard. Thus, for maximum energy consumption, the protective element should function as an elastic element for a longer time, continuing to take on energy for its plastic deformation. A constructive solution (shape and dimensions) was proposed to meet this condition, a solution whose behavior was simulated under dynamic demand conditions specific to the impact with a light weapon (caliber 7,62). Figure 1.a shows the proposed constructive solution, which can be realized as follows:

- a hexagonal coupon inscribed in a circle with a diameter of 100 mm is cut from a plate of 5 mm thick HEA material (Figure 1.b); the hexagonal shape is recommended for surface coverings due to its proximity to a large number of elements (6 elements), thereby occupying a concrete position, with minimal positioning deviations;

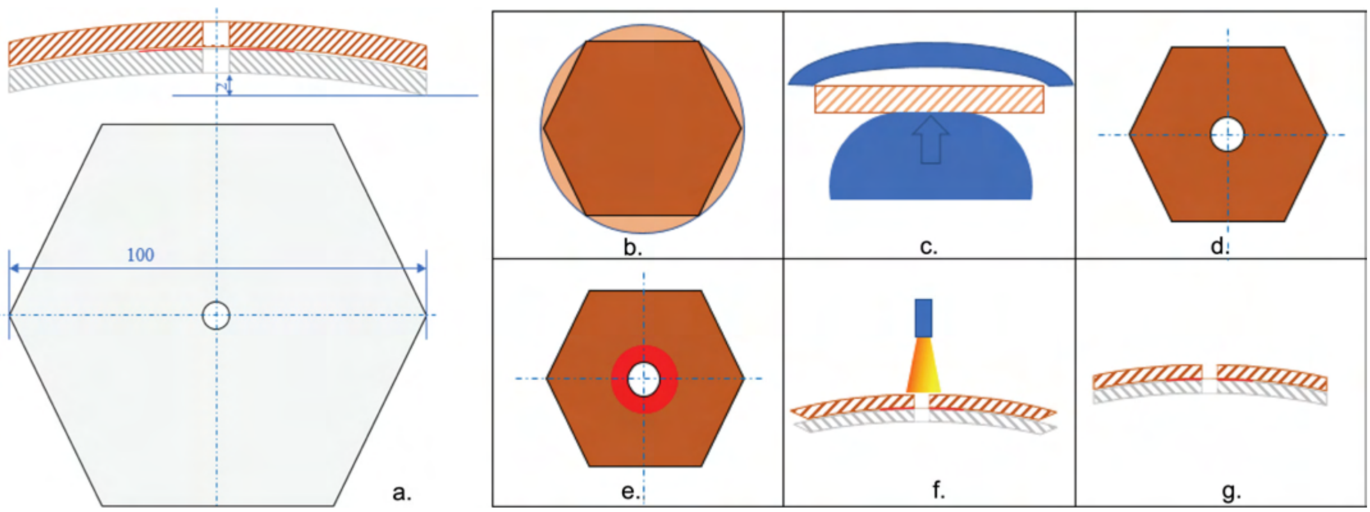


Figure 1. Realization of the protective element

Sudarea şi Încercarea Materialelor

- from a plate of aluminum alloy material A6061-T6 thickness 5 mm a coupon similar to the one cut from the HEA plate is cut;
- the two elements are plastic deformed, the maximum deformation arrow being measurable in the geometric center of the hexagon and having a value of 2 mm (Figure 1.c);
- in each of the two cut and deformed elements, a central hole having a diameter of 6.5 mm is made by drilling, for fastening bolts with a diameter of 6.0 mm (Figure 1.d);
- on the HEA element, a circular alloy layer is deposited around a hole of about 20 mm with a working temperature of maximum 620 °C (Figure 1.e);
- The two hexagonal elements are bonded using the alloy deposited on the HEA element and a gas flame placed on the outer surface of the HEA (Fig.1.f)
- After the connection is completed, the assembly is allowed to cool naturally to room temperature.
- The sides of the hexagon are machined from aluminum alloy, making a flat edge that allows the joining of two neighboring elements, without covering the HEA material on the surface to be protected (Fig.1.g).

3. Simulation on dynamic load of protective element

In order to optimize the shape and dimensions of the protection element, dynamic simulations of its behavior were performed, the conditions for requesting the verified geometric model being chosen so as to get as close as possible to the actual impact situation between the 7.62 caliber projectile and the protection element. For a correct image on the behavior of the protection element, the circular shape from which the hexagonal protection element comes from was considered in simulations. The simulation conditions are presented in Figure 2. The simulation results are presented in Figures 3 to 6.

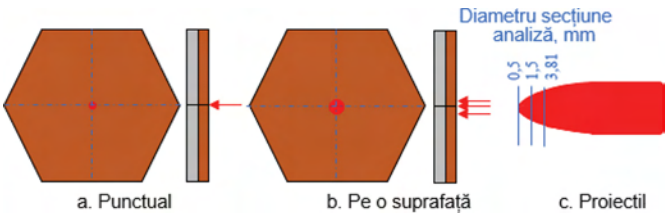


Figure 2. Simulation conditions

Figure 3 - The simple composite solution, without pre-deformations, shows a low impact behavior, the transferred energy producing a tension (von Mises) of the material at values of about 15-20% of its compressive breaking strength. URES displacements and ESTRN deformations have very low values, given that the protection element is shielded. However, the values create a special attention, given that the projectile considered in the simulation is one specific to small arms, having the size 7.62 and made of steel. An increase in the transferred energy, by using harder or larger caliber projectiles, will change the calculated stress values in the sense of increase.

Figure 4 - By changing the position of the place of impact, from the center of the element, where the fixing system exists, towards the edge of the element, the situation presented above is maintained, with a good behavior of the composite assembly.

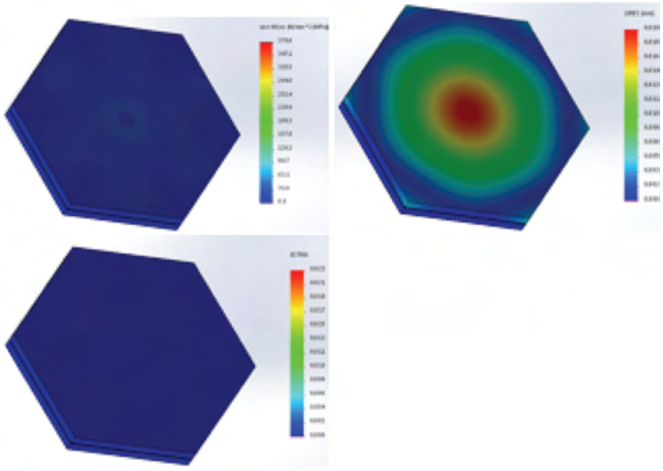


Figure 3.

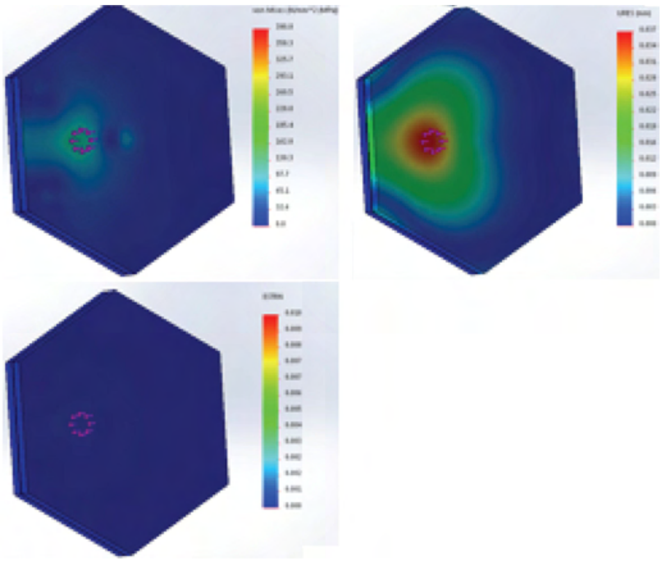


Figure 4.

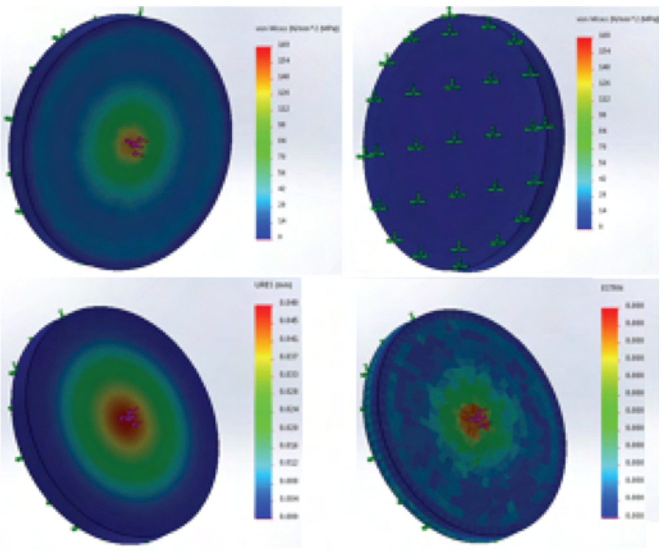


Figure 5.

Figure 5 - The transition to the pre-deformed version of the protection element is evidenced by a measure that halves the tension of the material: from 380 N / mm^2 to about 170 N / mm^2. The reduction of the voltages is due to an additional energy

consumption, a good part of the received energy being consumed by the material to deform initially elastic and then plastic (on the distance of 2 mm, the maximum arrow in pre-deformed state). The displacements and deformations are doubled, but the material is requested in half. There is the possibility of optimizing the new constructive solution by introducing in the cavity produced by preforming a dense foam, which in turn increases the energy consumption.

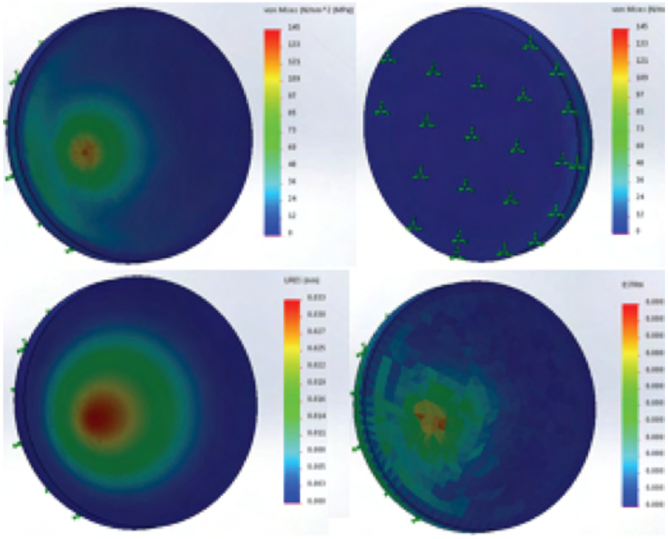


Figure 6.

Figure 6 - Exit from the center of the protection element, towards the edge, slightly reduces the tensions produced, given that the material stretched to preforming consumes energy to overcome the edge crunching produced by the stamping process. The displacements and the deformations decrease, the material being obviously hardened by crushing.

4. Tehnology for positioning and fixing of the protective element

The positioning and fixing of the protection element on the body of the armored vehicle can be done in a non-removable or removable mode. Given that any additional mass addition produces two negative effects, namely reducing cruise speed

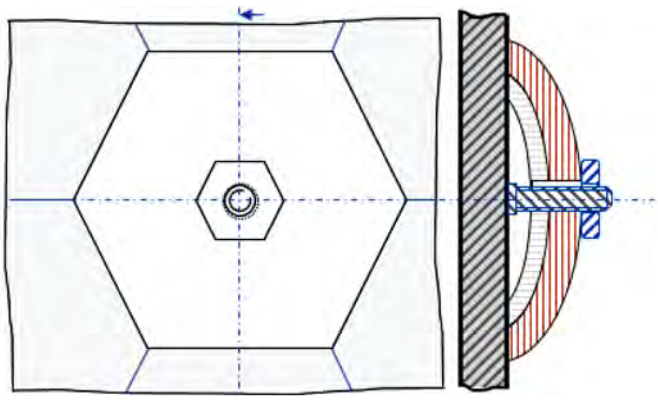


Figure 7. Technical solution for mounting the protective element

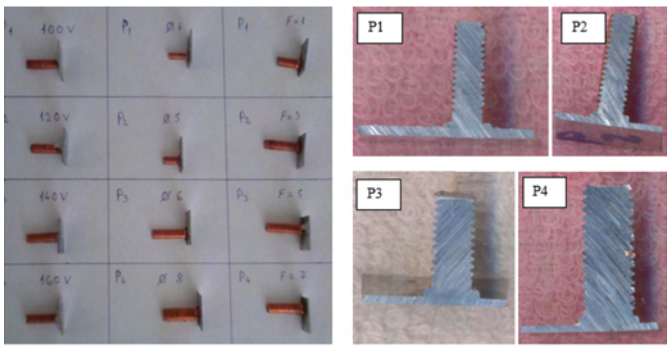
and increasing fuel consumption, it is considered appropriate to adopt the second option: the removable mount [5]. After a critical analysis of the main possible systems for removable fixing of the protection elements, the evaluation criteria being the speed of assembly-disassembly of the element, the costs, the speed and the precision of achieving the fixing of the individual protection element and of the protection element in conjunction with the elements of the neighboring protection, the constructive solution of the welded mounting of a threaded bolt on the body of the armored vehicle was adopted.

Stud welding is a technology of assembling a bolt on a surface, with an extremely low degree of damage to the two basic materials and with a process speed of fractions per second. For these reasons, of all the assembly procedures analyzed for the present application, the variant of welded energy storage of the threaded bolt was adopted. The design of the welding technology involved the choice of values for the set of welding parameters specific to the welding with stored energy, the application of these parameters and the quality of the realized joint.

Welded samples with bolts 4, 5, 6 and 8 mm in diameter were performed to verify the possibility of choosing any of these variants for the given application. Figure 8.a shows the welded samples. The samples were examined visually macroscopically, finding that none contained discontinuities in the weld material. Figure 8.b. shows two examples of welded joints, sectioned to highlight the interior of the weld.

Table 1. Stud welding technology applied

Priming spring by lifting with stored energy	
Parameter	Value
Bolt diameter, d_b, [mm]	6
Capacitor capacity, C [mF]	66
The voltage in the secondary, [V]	140±40 (variation)
Lifting height, L [mm]	1
Diving depth, P [mm]	1
Diving speed, v [m/s]	0.8
Force, F [div]	3/9



a. b.

Figure 8. Welded samples using stud welding
a. welded samples, b. welded samples considered for visual examination

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Calendar of International and National Events

2019			
9 Dec.	17th International Symposium On Tubular Structures (Ists17)	Singapore	https://www.ists17-singapore.org/
5 - 7 Dec.	NDE 2019 - Conference and Exhibition on Non-Destructive Evaluation	Bangalore, India	https://since2019.org/
2020			
27 - 29 Jan.	International Conference of Welding, Joining and Additive Manufacturing - Organized by AEAI.	Tel-Aviv, Israel	https://www.aeai.org.il/welding2020
26 - 30 Apr.	SPIE Smart Structures + Nondestructive Evaluation 2020	Anaheim, USA	https://www.spie.org/
14 - 15 May	International Symposium on Structural Health Monitoring and Nondestructive Testing (SHM-NDT 2020)	Québec City, Canada	https://www.shm-ndt2020.gel.ulaval.ca/home/
19 - 22 May	Young Professional International Conference and WRTYS 2020	Kiev, Ukraine	https://ypic2020.com/
27 - 29 May	4th International Congress on Welding & Joining Technologies - 3rd IIW International Congress in the Western European Region	Sevilla, Spain	http://www.cesol.es/congress2020/index-EN.html
10 - 12 Jun.	ITSC 2020 - International Thermal Spray Conference and Exposition	Vienna, Austria	http://www.dvs-ev.de/itsc2020/
19 - 24 Jul.	THE 73rd IIW Annual Assembly and International Conference	Singapore	https://iiw2020.com/