Proceeding of the 2nd International Seminar and Conference on Global Issues (ISCoGI) 2016: European and Asian in the Age of Globalization: Cooperation and Challenge
Wahid Hasyim University, Semarang, Indonesia. Nov. 25-26, 2016
Paper No. A.4

Ballistic Resistance Plates: Review of the Metallurgical Science and Al-Kahf 95-97

Helmy Purwanto
Wahid Hasyim University, Department of Mechanical Engineering, Faculty of Engineering,
X/22 Menoreh Tengah Street, Sampangan, Semarang, Indonesia 50236
Ph.D Student in Department of Mechanical Engineering, Faculty of Engineering, Brawijaya University,
Mayjend Haryono Street, Malang, Indonesia 65145
helmypurwanto@unwahas.ac.id

Rudy Soenoko, Anindito Purnowidodo
Brawijaya University, Department of Mechanical Engineering, Faculty of Engineering,
Mayjend Haryono Street, Malang, Indonesia 65145

Agus Suprapto
Merdeka University, Department of Mechanical Engineering, Faculty of Engineering,
Terusan Raya Dieng Street, Malang, Indonesia

Abstrak-Tujuan dari tulisan ini adalah mengulas baja tahan balistik dari prespektif ilmu metalurgi modern yang juga terdapat dalam kitab suci Al-Quran. Baja adalah salah satu material logam yang banyak diaplikasikan sebagai material tahan balistik. Karateristik balistik adalah kemampuan menahan tumbukan dari proyektil yang melaju pada kecepatan sangat tinggi. Plat baja telah banyak dikembangkan sebagai material tahan balistik dan menjadi pilihan utama sebagai bahan kontruksi kendaraan tempur (armored fighting vehicle :AFV). Dengan pemaduan dan perlakuan panas pada baja dapat meningkatkan kekerasan, kekuatan, ketahanan impak dan ketahanan balistik. Pemaduan dengan unsur nikel (Ni), kromium (Cr), molibdium (Mo), danMangan (Mn) pada saat peleburan dapat meningkatkan kekerasan. Proses perlakuan panas dengan celup dapat memaksimalkan kekerasan dan proses temper dapat meningkatkan ketangguhan. Penambahan unsur "tembaga (Cu)" dengan cara memanaskan baja dibuat dinding yang tak seorang pun mampu mendaki dan melubanginya seperti yang terdapat dalam Al-Quran Surat Al-Kahfayat 95-97.

Kata kunci**:** ketahanan balistik, pemaduan logam, perlakuan panas, Al-Kahfi 95-97

Abstract-The aim of this paper is to review steel as ballistic resistance plate (armor plate) from modern metallurgical science which has also been revealed in Holly Quran. Steel is one of the metal materials has been widely applied as ballistic resistant materials. A ballistic characteristic is the ability to put a halt projectile at very high velocity. Steel plate has been developed to improve armor material and was still the main choice as a material for armored fighting vehicle (AFV) construction. With the alloying of the steel and heat treatment process can improve hardness, strength, impact resistance and ballistic resistance. Alloying with elements of Nickel (Ni), chromium (Cr), molybdenum (Mo) and manganese (Mn) in the melting process may increase hardness. Heat treatment by quench can maximize hardening and tempering can improve the toughness. The addition of the element "copper (Cu)" by means of heating the steel as adam (boundary walls) are impassable and impenetrable have been demonstrated in Holly Quran Surah Al-Kahf verses 95-97.

Keywords**:** ballistic resistance, alloying, heat treatment, Al-Kahf 95-97

1. Introduction

Steel is one of the metal materials which widely applied in construction engineering. Steel has the properties of easily processed, manufactured, has high strength and can be engineered to improve its physical and mechanical properties. Steel is alloyed with the main elements of Iron (Fe) and Carbon (C) and added some elements to make steel with special properties. Ballistic resistance steel (armor/armor steel) is steel with a combination of hardness and toughness that is able to withstand the pace of bullets or projectile. Ballistic resistance material's characteristics can clearly be identified on the mechanisms for distributing cracked by the projectile impact (Siradjet al., 2010).The ballistic resistant steel is used in the world of defense and security for protection against projectiles and other explosive materials.

In the defense world, ballistic resistance steel made in the form of plates is used as construction materials of the combat vehicles such as armored fighting vehicle (AFV).The use of armor material in the form of plate should have two main functions, namely the protection function and construction functions (Rahmalina, 2012).The success of combat vehicles is based on the ability to accomplish the mission (Brinson et al., 2012), the missions in the form of the chase, attack and defense. Steel compared to other materials such as aluminum and polymer is still a choice to be developed as ballistic resistance materials mainly for AFV. Since steel is easily processed, welded and can be used as the main structure as well as well as projectile protector (Dimeski and Srebrenkoska, 2014). Disadvantages of steel compared with armor composite materials, aluminum armor or polymer is the large density, this resulting in the heavy constructions, so it takes a large driving power, efficiency and low agility (Montgomery and Chin, 2004). Although other materials have been developed, but steel is still the main material for combat vehicles (Kilic and Ekici, 2013).The use of steel as the equipment and body protection against enemy attacks is mentioned in the Quran (QS. Al Anbya 21:80) "*And We taught him the fashioning of coats of armor to protect you from your [enemy in] battle. So will you then be grateful.*"

Islam prioritizes peace and brotherhood but is allowed to defend themselves from the enemy as in (QS. Al Haj 22:39) "*Permission [to fight] has been given to those who are being fought, because they were wronged. And indeed, Allah is competent to give them victory*".And Allah has created a strong iron, so that humans can exploit and wear (QS. Al Hadid 57:25) "*We have already sent Our messengers with clear evidences and sent down with them the Scripture and the balance that the people may maintain [their affairs] in justice. And We sent down iron, wherein is great military might and benefits for the people, and so that Allah may make evident those who support Him and His messengers unseen. Indeed, Allah is Powerful and Exalted in Might*".

Steel Applications as the ballistic resistant material has been developed and continue to be developed in the modern era and the creation of steel as a protective material has long been revealed in the Qur'an. This paper aims to summarize and review the steel material as ballistic resistance materials in terms of modern metallurgical science and theology of the religion of Islam as stated in the Quran.

2. Metallurgical Characteristics

The ballistic resistance of the steel is complex functions from mechanical properties of steel i.e. yield stress, tensile stress, hardness, elasticity, and impact toughness. The properties cannot be used to predict the ballistic resistance, optimal combination of strength hardness and toughness are important factors in improving ballistic resistance (Jena et al., 2010). To obtain the characteristics of ballistic resistant, steel is alloyed with certain elements during melting and heat treatment processes and followed with quenching and tempering. Quenching is heating at an austenitic temperature and hold and then quick cooling to increase hardness. Tempering is heating at a temper temperature and then slow cooling is performed to eliminate the residual stress in the quench process and to increase the toughness.

The hardness of Ballistic resistant steel range 477 HB - HB 534 by a margin of variation of each measurement sample former stamping diameter not exceeding 0.15 mm. The hardness is measured by reference to ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials (MIL-A-46100D, 2007).The higher the hardness value, ballistic resistance increases, but at a certain value ballistic

resistance decreases back (Dikshit et al., 1995).While Jena et al, 2010a reported that the hardness cannot determine the ballistic resistance of the steel.

Behavior of tempering treatment resulting in ballistic resistance steel plate ability after quenching in oil, the higher the tempering temperature, depth of penetration (DoP) of the projectile is deeper (Mishra et al., 2012). Adiabatic shear bands (ASB) are formed around the hole due to the ballistic impact. ASB is emerging as a manifestation of instability thermo mechanical that produce large deformation shear strain in a narrow area (Molinari et al., 2002).

Hardness levels are able to influence the form of the hole of projectile impact. Petaling shape occurs in the soft plate and plug in occurs at the hard plate and cracked or broken for the very hard plate (Karagoz et al., 2008). The holes shape and impact by the impact of bullets on a plate as shown in Figure 1.

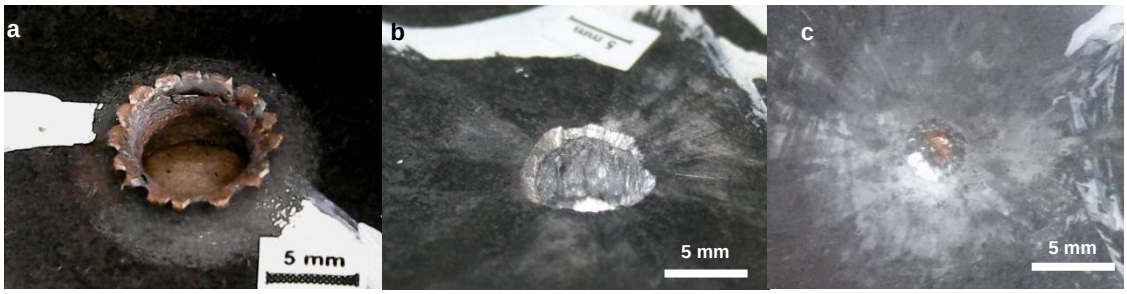

Fig.1. Projectile 5.56x45 mm caliber ballistic impact on plate 6 mm of thickness(a). soft plate (b).hard plate(c).hard plate (stopped)

Ballistic resistant steel is a type of alloy steel which generally contains additional elements such as element Nickel (Ni), Chrome (Cr) and Molybdenum (Mo).The addition of these elements or alloying are able to increase the hardness, especially Mo elements like those used in tool steel (Siraj et al., 2010).Typical armor steel contains austenite carbide formed from the elements, usually molybdenum, chromium, manganese and nickel with some carbon, to produce steel with high toughness that can withstand ballistic impact (Karagoz et al., 2008). The addition of the element manganese (Mn), Nickel (Ni) and Chrome (Cr) in lowcarbon steel to produce high strength low carbon steel martensitic and heat treatment process is carried out by using a tempering (Maweja and Stumpf, 2008). The additional chemical elements can change the atomic structure formed on the alloy. Alloying process and heat treatment is cause ballistic resistance martensitic steel. Alloying with chemical elements and heat treatment is to improve microstructure and morphology (Maweja and Stumpf, 2008).

Manufacture and additions of material arranged in layers on a steel plate has also been done to improve the ballistic resistance. Plate layers of different materials are combined to form a sandwich arrangement which is made to combine the advantages of each material and reduce the weaknesses of each. Making the sandwich material was developed due to single plate thickness in construction for the needs of single plate thickness are insufficient to meet the specifications and resistance to ballistic (Zukas and Schefflerb, 2001). Steel with different hardness created with layered ballistic results are shown better resistance to soft steel plates on the front compared with the opposite configuration (Bandanadjaja, et al., 2008).

Composite sandwich is able to withstand the high velocity ballistic impact (HooFatt and Sirivolu 2010) and composite sandwich with a core of epoxy is capable of absorbing impact energy (Lim et al., 2004). The first layer of the armor with composite sandwich is made for the purpose of collecting and breaking the tip of the projectile while the next layer and the back cover (back-plate) serves to absorb the kinetic energy of the projectile to stop the speed (Naik et al., 2012)on the ceramic-rubber composite sandwich (Roeder and Sun, 2001). Each layer of the ballistic panel has a different function, the main

function of the front layer is to absorb the kinetic energy of the projectile, stabilizers, deflection and deformation, while the plate next layer appears to absorb the kinetic energy and ballistic fragments (Shanel and Spainel, 2014). Structure of ballistic resistant composite sandwich with a variety of materials is illustrated in Figure 2.

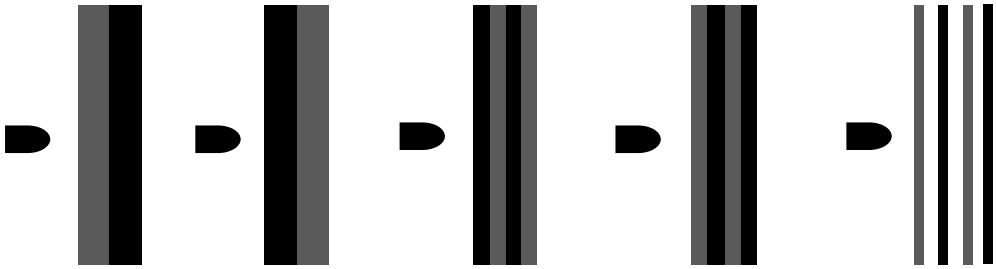

Fig. 2. Schematic sandwich ballistic panel (Mohotti,dkk. 2013; Teng, dkk. 2008; Ben-Dor, 2012)

Ben-Dor (2012) reviewed and concluded that the ballistic characteristics of the layered plate were (1). Damage layered plate depending on the distance between the layers, (2). the number of layers, (3). varying the type of material and the sequence layer, (4). extra layers affect the speed of the impact and (5). Form the ends of bullets used.

3. Surah Al Kahfi 95-97

The holly Quran revealed in the 6th century is a guide for Muslims. Qur'an was revealed gradually and sometimes waspreceded to related events. One of the surah in the Qur'an is Surah Al Kahfi. It contains the story of the prophet Khidr with the prophet Moses, the story of Dzulkarnain, Ya'juj and Ma'juj (Gog and Magog) as well as several other important events and still contains a mystery (Hamzah, 2007), and the story of Dzulkarnain still contains many secrets (Taufik, 2009).

In the Al Kahf, Dzulkarnain was a king with the power, position and have the tools and equipment required to protect poor people. Dzulkarnain punish the wrong people and provide and also protect the good and faithful people. Dzulkarnain built an iron wall to protect the nation from the attack of Gog and Magog (Fachruddin, 1992). Stories of Dzulkarnain in the past arethe history of religion which is almost exists in all religions (Taufik, 2009).

Surah Al-Kahf verses 95-97are :"*Dzulkarnain said, "That in which my Lord has established me is better [than what you offer], but assist me with strength; I will make between you and them a dam"*" (QS. Al Kahf 18:95). "*"Bring me sheets of iron" - until, when he had leveled [them] between the two mountain walls, he said, "Blow [with bellows]," until when he had made it [like] fire, he said, "Bring me, that I may pour over it molten copper*" (QS. Al Kahf 18:96)."*So Gog and Magog[Ya'juj and Ma'juj]were unable to pass over it, nor were they able [to effect] in it any penetration*" (QS. Al Kahf 18:97).

Iron or steel are created as a strong material and can be used by humans. Iron can also be used as protective clothing in a battle (armor).Processing iron into a strong material is also explained by the heating and the addition of the element. Iron can be made into strong walls to protect from an attack. To make the strong iron walls, a smelting process is needed by heating. The addition of "copper" element in hot conditions makes the iron stronger and nobody is able to pass or cut out / through.

4. Conclusion

From the science of modern metallurgy and Al Kahf there are similarities and it can be concluded:

1. Iron is a very strong material that can be utilized in the construction, especially ballistic-resistant construction or for protection from attack.

2. To make steel armor, the integration process (alloying) is made with other elements which in the Qur'an it says "copper" in hot conditions and followed by heat treatment to further improve the toughness.

References

Bandanadjaja, B., Basuki, A. & Siswosuwarno, M., (2008), Perilaku Balistik Baja Komersial SCr 440 dengan Kekerasan Berlapis (dual hardness) dalam Simulasi dan Eksperimen, Prosiding Seminar Nasional Teknoin Bidang Teknik Mesin, A 31 – A 36, Yogyakarta : UII

Ben-Dor, G., Dubinsky, A. & Elperin, T., (2012), Investigation and Optimization of Protective Properties of Metal Multi-Layered Shields: A Review, International Journal of Protective Structures, 3(3), pp. 275-291.

Brinson, L.C, Allison,J., Julie Chen, Clarke, D.R., Cowles, B., George, T., Greene, E., Harris, W.L. , Mehta, M., Olson, G.B., Saff, C., Tenney, D.R., Zok, F.W., (Committee On Benchmarking The Technology And Application of Lightweighting), (2012), Application of Lightweighting Technology to Military Aircraft, Vessels, And Vehicle, Washington DC: National Academy Press, pp. 93.

Dikshit, S.N., KutumbaRao, V.V. & Sundararajan G., (1995), The influence of plate hardness on the ballistic penetration of thick steel plates, Int J Impact Eng, vol. 16, pp. 293-320.

Dimeski, D. & Srebrenkoska, V., (2014), The Role of Contemporary Ferrous And Nonferrous Materials In Ballistic Protection Of Military Vehicles. Prociding VIth International Metallurgical Congress. Ohrid.

Fachruddin, H.S., (1992), Eslikopedia Al-Qur'an, Rineka Cipta, Jakarta, pp. 644.

Hamidi bin Hamzah Abu Zaid., (2007), Munculnya Ya'juj dan Ma'juj di Asia: Mengungkap Misteri Perjalanan Dzulkarnain ke China, Almahira, Jakarta, pp. 1.

HooFatt, M.S. & Sirivolu, D., (2010), A Wave Propagation Model For The High Velocity Impact Response of A Composite Sandwich Panel, International Journal of Impact Engineering, vol. 37, pp. 117–130.

Jena, P,K,, Mishra B.I., Ramesh. B.M., Babu, A., Singh, A.K. & Siva Kumar, K., (2010a), Effect Of Heat Treatment on Mechanical And Ballistic Properties Of A High Strength Armour Steel, International Journal of Impact Engineering, 37, pp. 242–249.

Karagoz, S., Atapek, H. &Yilmaz, A., (2008a). A Fractographical Study On Boron Added Armor Steel Developed By Alloying And Heat Treatment To Understand Its Ballistic Performance, 13th International Conference On Applied mechanics And Mechanical Engineering, Cairo.

Kılıç, N. & Ekici, B.,(2013) Ballistic Resistance of High Hardness Armor Steels Against 7.62 Mm Armor Piercing Ammunition, Materials and Design, 44, pp. 35–48.

Lim, T.S., Lee, C.S. & Lee, D.G.,(2004), Failure Modes of Foam Core Sandwich Beams under Static and Impact Loads, Journal Composite Material, 38 (18), pp. 1639–1662.

Maweja, K. & Stumpf, W., (2008) The Design of Advanced Performance High Strength Low-Carbon Martensitic Armour Steels Part 1, Mechanical Property Considerations, Materials Science and Engineering A, 485, pp. 140–153.

MIL-A-46100D (MR) w/INT Amendment 2. 13 July 2007. Military Specification: Armor Plate, Steel, Wrought, High-Hardness. USA.

Mishra, B., Jena, P.K., Ramakrishna, B., Madhu, V., Bhat, T.B. & Gupta, N.K., (2012). Effect of Tempering Temperature, Plate Thickness And Presence Of Holes On Ballistic Impact Behavior And ASB Formation Of A High Strength Steel, International Journal of Impact Engineering. 44 pp. 17-28.

Mohotti, D., Ngo, T., Mendis, P. & Raman, S., N., (2013), Polyurea Coated Composite Aluminium Plates Subjected To High Velocity Projectile Impact, Materials and Design. 52 pp. 1–16.

Molinari, A., Musquar, C. & Sutter, G., (2002), Adiabatic Shear Banding In High Speed Machining of Ti–6Al–4V: Experiments and Modeling, International Journal of Plasticity, 18, pp. 443–459

Montgomery, S. & Chin, E., (2004) Protecting a Future Force- A New Generation of Metallic Armors Leads The Way. AMPTIAC Quarterly. 6.

Naik , N. K., Kumar, S., Ratnaveer, D., Joshi, M., &Akella, K.,(2012), An Energy-Based Model For Ballistic Impact Analysis of Ceramic-Composite Armors, International Journal of Damage Mechanic.

Rahmalina, D., (2012), Pengembangan Komposit Matrik Aluminium Sebagai Material Armour dengan Keunggulan Karateristik Balistik. Disertasi Program Doktor (tidakdipublikasikan) Departemen Teknik Metalurgi dan Material Fakultas Teknik. Jakarta: Universitas Indonesia.

Roeder, B. A. & Sum, C. T., (2001), Dynamic Penetration Of Alumina/Aluminum Laminates: Experiments And Modeling, International Journal of Impact Engineering. 25 (2), pp. 169–185.

Shanel dan Spainel, (2014), Ballistic impact experiments and modelling of sandwich armor for numerical simulations,Procedia Engineering, 79 pp.230 – 237.

Siradj, E.S. , Priyono, E., Mulyono, Ahyani, M. & Rakhmawati, D., (2010), Pengaruh Manufaktur Terhadap Performance Material Armour untuk Ranpur. Laporan Akhir Program Insentif Peningkatan Kemampuan Peneliti dan Perekayasa. Kementerian Riset dan Teknologi. Jakarta. Diakses melalui http://km.ristek.go.id/index.php/klasifikasi/detail/21505/. Diakses tanggal 12 Februari 2014.

Taufik., (2009), Dzulkarnain dalam Al Quran, Skripsi Jurusan Perbandingan Agama Fakultas Ushuluddin Universitas Islam Negeri Sunan Kalijaga, Yogyakarta.

Teng, X.,Wierzbicki, T. & Huang, M., (2008), Ballistic resistance of double-layered armor plates, International Journal of Impact Engineering, 35(8), pp. 870–884.

Zukas, J.A. dan Schefflerb, D.R., (2001), Impact Effects in Multilayered Plates. International Journal of Solids and Structures.38 (19), pp. 3321–3328.