DETONICS (AND BALLISTICS) IN SOUTH AFRICA : A PAST, PRESENT AND FUTURE PERSPECTIVE

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Detonics, the application of the science of detonation and related phenomena, plays an important role in energetic material studies within the wider field of ballistics. A small contingent of researchers and applicators within the commercial and defence community of South Africa have contributed to advancement of knowledge in this field. Due to historical circumstances and the unique requirements of the Southern African environment some of the contributions made were novel and feature as building blocks of much wider used current technology. In this paper a perspective is given on the South African scientific contributions related to this field and an assessment of future local challenges is made.

HISTORY OF DETONICS IN SOUTH AFRICA

Gunpowder was probably introduced to Southern Africa by Arab or Asian traders earlier than 1652 when Jan van Riebeeck landed in the Cape and colonised it as a replenishment station for the Dutch East Indian Company. It is however certain that between 1652 and 1896 gunpowder played a major role in various battles for control of the region [1]. The true introduction of detonics to the Southern African continent came with the discovery of gold in the Witwatersrand and the opening of “De Zuid Africaansche Fabrieken voor Ontplofbare Stoffen” by president Paul Kruger, at Modderfontein in 1896 [2]. Dynamite was a sought after commodity in the mining of the hard, quartzitic gold bearing rock in the Highveld area of the Zuid Africaansche Republic (ZAR). The initiative of Kruger to grant a concession to a European firm to monopolize dynamite was an attempt to increase the independence of the ZAR [3]. The interplay between commercial and military interests would be a perennial feature in the development of the explosive industry in South Africa. This would directly lead to the establishment of another factory, the Cape Explosive Works factory in Somerset-West, after the Anglo-Boer war (1899-1902) [4]. By 1907 the combined annual production of the two companies exceeded half a million (50lb) cases. In 1909 a third competitor was established in Umbogintwini by Kynoch and Company. By 1911 the explosives industry was by far the largest manufacturing industry in the country and one of the biggest in the world [4].

Little is documented about the individual local expertise existing in the explosives industry during the period before WWII but it is certain that the use of explosives in mining played a major role in developing this expertise. Dr Franz Hoenig, an Austrian from the Nobel explosives factory in Hungary, was the first manager of the Modderfontein factory and explosives workers were recruited from various Nobel factories in the world [5]. Detonators were manufactured at both the Moddefonteintein and Cape Explosive Works sites after the First World War. With the amalgamation of the four largest chemical companies in Britain, the giant African Explosives and Chemical Industries Limited (AECI) was formed in South Africa in 1924 [5]. Research and development during this period was aimed at improved chemical processes and the focus remained commercial explosives. Defence related detonics activities in South Africa were minimal before WWII

Grenades, mines and bombs were manufactured in South African during the Second World War and the South African Engineer Corps, as part of the Allied forces, was initiated into mine warfare in North Africa. Two South Africans, Lieutenant Colonel Mill Colman and Major SJ du Toit are independently credited with the initial idea which led to the development of the flail tank for mine clearance [6]. This was also the start of a long association of South African forces with the detonics of countermine warfare.

When the war ended in 1945, the prime minister, Field Marshall Jan Smuts, instructed the establishment of a Council for Scientific and Industrial Research (CSIR). Smuts, an intimate advisor of British Prime Minister Churchill during WWII and an amateur scientist, appreciated the impact of technology on the conduct of war [7]. There was also limited arms production in South Africa after the war. The Defence Production Office was established in 1951 and a British company, BSA, set up a workshop in Lyttelton [8]. This institution later became the Lyttelton Engineering Works. In 1963, with the threat of an arms embargo due to the internal policies of the Nationalist government, a National Institute of Rocket Research was established within the CSIR which, in 1965, became the National Institute for Defence Research [7]. The Armaments Development and Production Corporation of South Africa was established in 1968 and absorbed most of the defence related research organisations by 1977 when it amalgamated with the Armaments Board and officially became the Armaments Corporation of South Africa (Armscor) [9]. Detonics featured prominently at a number of institutions under the Armscor umbrella with dedicated investments in people and facilities at Somchem, Naschem, Mechem, Advena and Pretoria Metal Pressings (PMP) and Swartklip during the period 1978 to 1991. In 1992 most of these facilities were separated from Armscor

as part of a new military-industrial and technological conglomerate, Denel (Pty) Ltd, with the State as the only shareholder [10].

In 1994 the political face of South Africa changed with the first inclusive and free election and the inauguration of an ANC led government. The previously heavily subsidised parastatals were restructured to operate as independent business enterprises. Although this course of action was a natural consequence of the sharp decline in demand for defence equipment in the new dispensation, it inevitably led to retrenchments and some loss of expertise. The Denel detonic facilities were largely combined into the Denel Munitions group in 2006 [11]. Denel adopted a turnaround strategy to obtain international equity partners and in September 2008 Rheinmetall took a 51% share in Denel Munitions to form the new company Rheinmetall Denel Munitions (RDM) [12].

The current custodians of detonics in South Africa can be divided into two groups, the commercial side and the defence group. African Explosive Limited (AEL) and Sasol Dyno Nobel (SDN) [13] are major role players in the commercial group, with other explosive manufacturers, consultants and the various blasting agents operating in the mining environment making up the rest of the group [14]. In the defence group, RDM makes up the largest contingent outside of the SANDF, together with the Landward Sciences group of the Defence Peace Safety and Security (DPSS) division of the CSIR. There are also two organisations, the National Institute for Explosive Technology (NIXT) and the South African Ballistics Organisation (SABO) that foster interest and interaction in this field.

SCIENTIFIC CONTRIBUTIONS IN DETONIC RELATED FIELDS

The unique characteristics of the Southern African environment as well as geopolitical developments in the region over the past five decades led to some indigenous developments in detonic related fields. As the focus of the paper is on the ballistics related detonic activities, contributions in the commercial field will feature only to a limited extent. A good overview of the achievements of AEL in the commercial field is found in *reference 5*. Furthermore, only contributions published in open literature are discussed which implicitly restricts the comprehensiveness of this overview.

The initial significant investment in detonic research started within the Defence Research Unit of the CSIR during the late 1960's early 70's [7]. Research on the effects of landmine explosions was a direct consequence of the experiences of the security forces in the border regions [6].The CSIR did systematic detonic tests on

the effects of landmines during the 70's and 80's and this research pioneered the development of Mine Resistant Ambush Protected Vehicles (MRAP). Dr Venon Joynt, acknowledged as one of the founders of the monocoque V-hull MRAPs [15], was also instrumental in introducing this technology internationally [16-19]. Although the detonic work performed by this team from the CSIR (later Mechem, a division of Denel) was almost entirely empirical, innovative test methods were developed during this time to measure various parameters. One such example was the 'Bridge of Sighs', a device to measure the relative impulse from blast waves resulting from landmine detonations, as described in *reference 20*. From these types of measurements. conclusions were drawn and novel vehicle designs conceptualized to minimize the effects of landmine explosions. Over 5000 vehicles, incorporating blast mitigation measures, of more than 8 different designs, were built by the local industry for the security forces between 1977 and 1988. This directly contributed to reduction of fatalities from landmine incidents [6, 21].

The initial thrust of detonic activities in other areas of the defence field stemmed from Armscor munitions development in air-to-air, air-to-ground and surface-to-surface weapon programs in the late 70's early 80's [22]. The first defence detonic related contributions of a scientific nature at international symposia were made by Venter [23] and Szendrei [24] in 1983. The latter analytical contribution on the crater formation in metallic targets from shaped charge penetration was cited by many authors in the field [25-27]. Although the 17th International Congress on High Speed Photography was held in Pretoria in 1986 [28], South African scientists working in the defence field became increasingly isolated. A series of Rapid Physical Effects symposia were initiated by Dr Jean De Villiers during the 80's to foster local interaction [29] but proceedings were not openly published. A large compliment of the work in the defence field was of an applied and empirical nature, but some analytical work was demonstrated during this time [30]. Spin-off work from the development of shaped charge munitions was also published [24, 31]. The NIXT symposia were initiated in 1987 which, in particular, provided a forum for interaction between scientists in the defence and commercial sector [29]. At the first symposium, references on the design of plane wave generators [32], pyrotechnic mixtures for delay detonators [33] and the sensitivity of commercial explosives [34] can be found. The development of a local commercial emulsion explosives and its chemistry was discussed by Knight [35] at the second symposium. It also contains the first local reference to numerical modeling of explosive-metal interaction [36] and leveraging of military technology into the mining environment [37]. An interesting anecdote was captured in the program brochure of the latter symposium regarding the blasting work performed in the Du Toit's Kloof Tunnel project. For the blasting work in this 3.9km tunnel AECI provided 894 tons of locally developed Dynagel (water-resistant) commercial explosive, 314000 electric detonators and

255km of Cordtex™ detonating fuse. Also in the commercial field, the development of synchronized initiation systems for electronic detonators appeared in the 90's [38] and a number of detonic research contributions by the commercial groups are documented in the 1992 NIXT symposium proceedings [39].

After 1994, international exposure of defence related detonic research in South Africa improved. Papers were presented at the 1995 International Symposium on Ballistics [40-41] and a successful bid was made to host the 1998 International Symposium on Ballistics in South Africa [42]. The restructuring of the SA defence industry, however, left its mark and several specialists departed from the industry, some of whom continued to operate in the field as independent consultants.

Mine clearance and the development of mine clearing equipment continued to be a topic of interest and König, in particular, contributed to detonic research in this regard. Contracted by Denel for the development of line-charge mine breaching systems, anomalies in the blast effect perpendicular to such charges were identified, analysed and characterized [43]. König also implemented and improved a variety of techniques to study the sensitivity and reliability of initiation at explosive interfaces [44, 45].

The establishment of numerical modeling capability at most of the centers changed the mostly empirical and experimental nature of research in detonics from the 90's. Specifically, research in the shaped charge field benefitted. König [46] received the award for best paper on shaped charge technology at the 19th International Symposium on Ballistics. This covered work on non-initiating shaped charges, only one of the novel leading charge options researched for tandem warheads against explosive reactive armour at Denel Munitions [47]. Experimental work in the field of shaped charges, however, continued and dynamic testing, in particular, became important [48].

Although local research on energetic materials in the defence sector diminished after 1994, the adoption of an Insensitive Munition (IM) policy by the SANDF brought new challenges to the detonics community [49]. This topic which is quite intensively researched in Denel (and currently in RDM) has yielded significant contributions to the detonic and propulsion fields [50-55] up to the present.

CURRENT ACTIVITIES AND CHALLENGES FOR THE FUTURE

Interest from academic institutions in the field of detonics in South Africa has grown systematically since 1994 and the establishment of the Blast Impact

Survivability Research Unit (BISRU) at the University of Cape Town, under leadership of Prof Gerald Nurick, has played a significant role [56]. Basic research tangential to detonics has also been conducted at Stellenbosch University and the University of the Witwatersrand [57] for some time.

After more than a 100 years of service to the mining sector the commercial explosive industry still strives to continuously improve product performance with new technology. AEL remains a large role player in the African market [5, 58], but it now faces stiffer technological competition from other role players such as SMX (now SDN) and Omnia [59]. Experienced detonics experts such as Szendrei continue to be active in this sector and other role players also contribute to the application of new explosive technology in mining activities [60]. Future challenges in this area remain focussed on developing more innovative, efficient and safer explosives systems and blasting practices [5].

In the defense community, detonic activities are connected to the future requirements of the SANDF. Amidst funding constraints, the Defence Research and Development Board (DRDB) continues to manage South Africa's defence research portfolio and strives to align research to SANDF requirements [61]. Since the SANDF is becoming progressively more involved in peacekeeping missions, a balance needs to be found between the research into conventional warfare technology and that applicable to asymmetric threats. Methodologies to characterize materials will always be required in the detonics field [62]. The protection of vehicles against various threats is a continuing area of interest and a range of technologies in this regard is researched by the CSIR. The study of Improvised Explosive Devices (IED) and the characterization of various threats is a prerequisite for research into options for protection against such threats [63-65]. In the industry, in particular RDM and Denel, the implementation of IM-technologies is high on the agenda [54], but innovation in the design of conventional munition systems is set to continue. Examples are the development of an active armour munition with novel warhead solutions against various threats [66] and the development of an Insensitive High Explosive (IHE) preformed fragment (PFF) artillery round. The latter is claimed to be the first IHE PFF artillery projectile to be fielded in the world [67].

SUMMARY AND CONCLUSION

Despite being a small community with restricted research funding, significant contributions were made locally in detonics, both in the commercial field as well as in the defence sector. This was due to a unique set of historical, environmental, political and geographical circumstances.

In the commercial field, several world class technologies have been developed for the mining sector such as electronically synchronized initiation systems, new explosive formulations and blasting techniques. Research in the defence field was primarily of an empirical and analytical nature with heavy emphasis on experimental testing. Contributions of note were made in the fields of counter-landmine warfare, detonic design and IM technology.

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Many of local contributors to the detonics field have not been adequately credited for their contributions, made over the last few decades, due to the lack of international exposure and publication restrictions. This paper is dedicated to their efforts.

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