February this year Kalashnikov Concern announced that it was considering a joint venture in India with a new plant capable of manufacturing 50,000 weapons per year. It was suggested that any venture would involve the production of combat weaponry as well as firearms for civilian use. "India is a very promising market, and the best way to enter it is to set up production there," stated Alexei Krivoruchko, Chief Executive and part-owner of Kalashnikov Concern, in February 2014. "We will begin to set up production this year." [8]

Other Asian countries

Japan, an early adopter of MIM technology, is understood not to have any significant MIM firearms production, with its key markets being automotive, medical devices and industrial equipment. Likewise, there is understood to be little MIM firearms production in Singapore or Taiwan.

HIP in the manufacture of MIM firearms components

In a drive to deliver parts with the greatest possible performance, 50-60% of all firearms parts manufactured in North America today are Hot Isostatically Pressed (HIPed) to full density in order to improve toughness, ductility and fatigue strength. The need for a HIP process depends largely on the specific application and performance requirements of a MIM part.

Commenting on the reasons behind the growing use of HIP in the manufacture of MIM parts for the firearms industry, Dennis Poor, President of Kittyhawk Inc, a leading US provider of HIP services, told *PIM International*, "The obvious answer is that HIP will provide the end user with fully dense parts. That said it should also be noted that MIM can provide parts at a reduced cost, in a net or near net shape that eliminates or reduces machining costs and a fully dense part will have a significant positive impact on reliability, lowering field failures."

Poor noted, however, that there are a number of important considerations when considering the HIP of MIM parts, stating, "Many of the MIM components used in the firearm industry are small, thin walled, and have complex geometry making the part difficult if not impossible to straighten. It is therefore extremely important for the HIP provider to consider matching the correct cycle temperature to the part material and loading methods that reduce or eliminate distortion of parts. Diffusion bonding of parts loaded incorrectly must also be dealt with. Firearm parts also include an interesting and serious challenge to the HIP service providers as some parts have additional government regulations and controls requiring specialised licensing for 'any or all' entities handling the parts."

Bringing HIP into the MIM plant

Leading continuous MIM furnace manufacturer Cremer Thermoprozessanlagen GmbH, based in Düren, Germany, is developing a HIP system specifically for the processing of MIM parts. Ingo Cremer, the company's General Manager, told *PIM International*, "The MIM process is becoming more and more embedded in the weapons industry. In order to achieve the all-important dense and non-porous surfaces, HIP plays a key role. Part manufacturers, however, would much rather avoid sending components to HIP service firms, which takes a lot of time and adds cost. In addition, HIP service companies may be located in other countries and this requires the necessary knowledge of formalities, transportation modes and legal provisions."

Cremer added, "It is therefore becoming more and more important for the future development of the MIM industry to integrate the HIP process into the manufacturing chain of MIM parts as an essential link. It is obvious that we need to optimise plants with specifically adapted processes. Cremer Thermoprozessanlagen wants to play a role in this market with a new system that can process two production line sizes, 150 x 300 mm and 300 x 900 mm. Process time is reduced to a minimum thanks to the use of highly effective rapid cooling. The charge material is adjusted to the components and the maximum utilisation."

Cremer stated that as well as ensuring components reach full density, mechanical properties such as tensile strength and elongation are increased and machinability is improved, resulting in cost reductions for the whole manufacturing process, potentially helping MIM to replace forged and machined parts.

MIM versus Investment Casting

As a division of the Spanish investment casting company Ecrimesa, Mimecrisa has the opportunity to see the changing balance between the use of Investment Casting (IC) and MIM technology in the firearms sector. Mimescrisa's Manuel Caballero commented, "For us MIM and IC are complementary technologies; there are parts that for their size or metallurgical characteristics must be IC and other parts that are without doubt MIM parts as you can achieve better tolerances and reduce machining costs."

"Most of the small parts, say under 50 g, such as safeties, triggers, hammers and even heavy duty internal parts have moved to MIM. Saving on machining operations and better surface finish compensates for the higher costs of the injection moulding tool. The competition is now in bigger parts for new designs, however frames or slides are still mostly produced by investment casting and machining."

IC still has the distinct advantage over MIM in that the cast parts can be bigger or heavier than the MIM parts. Batch sizes with MIM, however, can be significantly higher thanks to the speed of the process and limited requirements for finishing operations. MIM parts can also be produced with greater material and energy efficiency, without the need for manual finishing operations, with more design details such as embossed lettering, blind holes, slides and thinner walls. Other advantages for MIM include superior tolerance control for smaller dimensions and the need for less space for the injection point as compared with investment casting gates.

CASE STUDY: Desert Eagle .50 AE

A case study that offers insight into the application of MIM technology into a firearm is that of Magnum Research's Desert Eagle .50 AE pistol. Founded in 1980, Magnum Research, Inc., based in Minnesota, USA, worked with US MIM manufacturer Phillips-Medisize Corporation to produce 12 of the 92 parts in the Desert Eagle .50 AE pistol by MIM [9].

This collaboration saw, for the first time, all components of the Desert Eagle pistol manufactured entirely in the United States. According to Todd Seyfert, Partner at Magnum Research, the move to domestic manufacturing of the Desert Eagle .50 AE not only reduced costs, but eliminated freight expenses and uncertainties around foreign currency exchange rates, as well as enabling

Fig. 14 MIM parts manufactured by Phillips-Medisize Corporation for Magnum Research's Desert Eagle .50 AE pistol (inset) [9]

CASE STUDY: MIM in Ruger's LCR® (Lightweight Compact Revolver)

In a keynote presentation given at MIMA's annual conference in 2012, and later reviewed in *PIM International* [10], Joseph J. Zajk, Chief Engineer, Pistols, at Sturm, Ruger & Co., Inc. offered an insight into the development of a new firearm and the factors that have to be considered before a component manufacturing route is selected.

Sturm, Ruger & Company, Inc., commonly known as Ruger® Firearms, was founded in Southport, Connecticut, USA, in 1949 by William B. Ruger and Alexander Sturm. Today the company is one of the US's leading firearms manufacturers.

Zajk explained that for over 50 years the company's famed reliability and value had largely been due to Ruger's expertise in precision investment castings and the process had become the company's technology of choice for producing small, intricate components. Investment casting is still at the heart of the company's component production capability with pistol barrels, slides, hammers, receivers, frames, bolts, hammer and triggers, to name just a few, all in high-volume production.

The trend towards more compact firearm designs with smaller, more intricate parts made investment casting these components challenging and Ruger turned to MIM to complement its expertise in investment casting. Zajk commented that William B Ruger Sr. once said, "The key is complexity of the component you are considering to make as an investment casting. If it isn't complex, the casting process is hardly beneficial." The same approach needs to be taken when applying MIM technology, suggested Zajk - if there's no complexity, there's no advantage.

Ruger's interest in MIM as a manufacturing process came at a time when the technology had reached the necessary level of maturity and the changing firearms market demanded smaller, lighter and more compact handguns that also offered performance improvements. Today, Ruger uses a select number of US-based MIM suppliers.

In 2009, Ruger introduced the LCR® (Lightweight Compact Revolver) (Fig. 15). This was Ruger's first clean-sheet revolver design in over 20 years and presented the company with the opportunity to design for MIM from the outset. Additionally, the revolver's small size and light weight meant that many of the components that the company traditionally investment cast were no longer a good fit for that process. Overall cost was also a concern, as Ruger was entering a highly competitive market. A number of MIM parts found application in the LCR®, as can be seen in Fig. 16.

One complex part from the LCR® was a star-shaped ejector. A MIM blank was produced that incorporated a deep through hole with a minimum draft. The requirement to gundrill and ream was eliminated and the hole established machining datum. Zajk stated that in this instance the MIM component required less machining than a casting, offered equivalent material properties and came in at a lower overall cost.

Fig. 15 Ruger's LCR® (Lightweight Compact Revolver), introduced in 2009 [10]

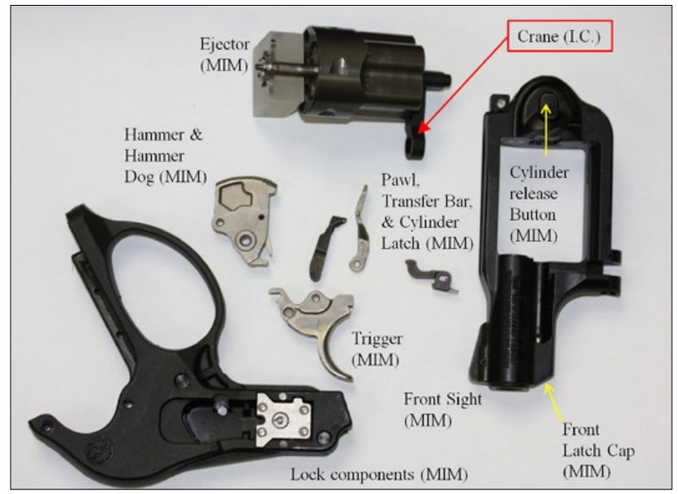

Fig. 16 Many of the components in Ruger's LCR® were specifically designed for MIM production [10]

Outlook

From a stabilising domestic US firearms market to a European industry hit by political sanctions and government regulation, MIM suppliers to this sector are currently having to navigate uncertain territory. What is clear, however, is that the industry is firmly established as a valued partner for gun manufacturers and that there is no doubt that the use of MIM parts in firearms is set to increase as new guns are developed.

Looking to future challenges, Parmatech's Rob Hall told *PIM International*, "I see three primary areas of focus for the MIM industry to further grow the firearms market. Firstly, we need to continue to drive forward with MIM process capabilities in order to improve the performance and value of the firearms components. Secondly, we need to expand beyond core internal components to larger components such as slides, barrels and cylinders. Finally, it is vital that we work closely with the OEMs in the initial design phase to provide the full benefits of the MIM process."

From a US market perspective MIMA's Bruce Dionne stated, "The growth of the firearms industry in the US has greatly supported the growth of the MIM industry and vice versa. Growth to date has been unprecedented and those businesses that support it recognise the energy that political and civil unrest adds to the system. Fear continues to drive new would-be gun owners to gun shops across the nation and those that supply the industry are certainly aware of the volatility. There will continue to be opportunities in this industry brought on by new products and designs and, when we take out the noise and volatility that has been in the system, we still see a year on year growing industry with opportunities for the future."

ARCMIM's Kevin Schwindt stated, "MIM offers reduced costs to manufacturers of firearms parts and it's a well accepted manufacturing process within the industry. I think we will continue to push parts size limits and reduce the time for new product development - as well as faster manufacturing times for products. For the MIM supplier that can be low cost and has the faster development time to delivery first off parts, they will continue to be the supplier of choice to any customers."

Matt Bulger, Vice President

Magnum Research to gain complete control of product quality and production and meet surges in market demand.

"Given the current economic climate worldwide and the loss of manufacturing jobs, we think it's important – even on our scale – to return manufacturing jobs to the United States. We're happy to be a part of this movement," stated Seyfert.

The material Philips-Medisize proposed for the MIM Desert Eagle parts was 42CrMo4, comparable to 4140 steel. "The material blued very well," stated Jim Tertin, Director of Manufacturing at Magnum Research, commenting on the way the material took to receiving black oxide treatment. "That's a big deal. Our guns have to shoot really well, but they also have to look really good. When we blue a part it can't turn maroon in a year. We blued, welded, and polished our test parts, and to this day, they're all still black."

Magnum Research provided Phillips-Medisize with Desert Eagle .50 AE part designs upfront and the two companies teamed together to work out dimension and tolerance issues to make the parts more manufacturable. The companies also identified a number of previously cast parts that could be Metal Injection Moulded. Phillips-Medisize created two multi-cavity moulds and eight single cavity moulds to make a total of twelve Desert Eagle .50 AE parts for Magnum Research. From start to initial part sample delivery, the development process took four months.