Appraisal of SME Casting Industry in Thailand

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Abstract—**Cast products form component parts in many manufacturing industries, especially in the automotive sector. To keep pace with the rapid growth of automotive and other manufacturing industries in Thailand the country's foundry industry has had to develop its production capacity and technical capability at a relatively rapid rate. The Thai-owned SME companies have had to build up their production capabilities without strong back-up experiences and technology. Limited investment, lack of applied R&D, inadequate testing and metrology services, plus a general shortage in engineering skills and overall training have significantly restricted their technical development. Against this background and with particular respect to the automotive SME sector, this short review examines some of the strengths and weaknesses of the Thai Foundry industry and the improvements that need to be made for companies in this sector to survive and prosper in an increasingly competitive quality-driven marketplace.**

Index Terms—**automotive SME sector, casting industry, current state, improvements needed, future development.**

I. Introduction

Over recent years quality management and process controls in foundries around the world have been significantly improved raising casting quality levels and increasing customer confidence in cast products. However, there is still room for improvement since the production of scrap castings continues to result in unacceptable levels of waste of raw materials, energy, and effort. Foundries are still wasting money because they do not pay sufficient attention to the metallurgical and other technical aspects of their operations. This generalization is particularly relevant to many foundries in Thailand where large scale manufacturing, notably in the automotive industry, has developed at a rapid pace. Following the continual expansion of motor cycle and vehicle assembly plants in Thailand there is a large market for the supply of automotive castings, but if Thai foundries, especially those in the SME sector, cannot become and remain technically competent and competitive enough, then business could be lost to overseas competitors due to the recent trend in global procurement of automotive assemblers. Many overseas foundries, especially in Europe and USA, satisfy the Quality System requirements of the major automotive assemblers. These foundries benefit from many years of experience in meeting these standards and in the implementation of Total Quality Management (TQM) and Continual Improvement including techniques such as Statistical Process Control (SPC), Failure Modes & Effects Analysis (FMEA), and Design of Experiments (DOE). Together with foundries in other countries, notably India and China where the automotive sector is also rapidly expanding, they provide intense competition for Thai foundries. Non-automotive casting producers also face the same challenges since the manufacturers of electronic equipment, electrical appliances and home fittings, etc. have now become just as demanding as the automotive industry in terms of quality, price and on-time delivery.

Around the world small foundries are finding that it is increasingly more difficult to survive. Over the last few years in Europe and the USA it has been hard for even competent small foundries to compete such that increasing numbers have gone out of business. Small foundries in Thailand face a different and more demanding set of problems when compared to their more mature competitors in Europe, Japan and USA. For example, in Thailand many shop floor workers are from an agricultural background and lack experience in industry and there is still only limited foundry craft and technician education and skills training. Small foundries cannot find funding to support training or invest in new equipment or technology, let alone attract and keep technical graduates or skilled staff.

Against this background this paper provides an outline review of the development and current status of the casting industry in Thailand with a focus on the small & medium sized enterprises (SME) that produce parts for the automotive industry. Towards the survival and future prosperity of these foundries some of the many difficulties that they continue to face are discussed and potential solutions or areas for improvement identified.

II. Development of The Casting Industry In Thailand

Cast metal has a long history in Thailand in that discoveries of Bronze objects, including cast spear heads, excavated at Ban Chiang near Udon Thani in the Northeast are believed to date from 3600BC [1]. Metal casting as a foundry industry in Thailand began to develop from the mid-19th century with the production of canons, weapons and hand tools. Gradually industrialization gave rise to many small and medium sized foundry shops scattered around Bangkok, and in the southern and eastern parts of the country. Industrial growth has accelerated in the last 30 or so years and Cast Irons (mainly Grey and Ductile grades), Cast Steels, Aluminium alloys, and Copper based alloys are all now produced as castings to supply the automotive and general engineering sectors. There are some well-established jobbing ferrous foundries producing a range of steel castings including High Manganese and Stainless grades and alloy cast irons such as Ni-Hard, Ni-Resists and High Chromium irons. Cu base alloys are mainly for marine, water, architectural and lighting applications.

During the booming decade (1987~1997), several large plants were established to produce high quality casting parts for the automobile and cement industries. Since then, in spite of the S.E. Asian recession, the automotive industry has grown steadily such that current annual capacity is around 2.7 million vehicles. This could reach 3 million during 2017 since several auto-producers in Thailand have increased the capacity of existing facilities or are building new plants. Currently Thailand is the 5th largest commercial vehicle builder in the world after China, Japan, Canada and Mexico, and is the 2nd largest producer of pick-up trucks behind the USA. In addition, around 2 million motorcycles are produced each year. Outside the auto sector most of the castings produced in Thailand are for electronic & electrical appliance, machinery, construction and agricultural applications.

There are no detailed production data just for the Thai castings industry since separate data on foundries does not appear to be recorded but are hidden in the statistics on the Iron & Steel and the Automotive Industries. Current capacity is estimated at 1 to 1.2 million tonnes of ferrous castings and around 120,000 tonnes of non-ferrous, most of which are aluminium base die-castings. High pressure diecasting for vehicle and electronic parts is well established together with low pressure die-casting of auto wheels. There are about 450 companies which produce cast products with about 80-90 % of these being classified as small to medium sized enterprises. The Thai Foundry Association currently has 83 ferrous foundries and 102 non-ferrous foundries listed as members. The large manufacturers are mostly subsidiaries of multi-national automotive companies from Japan. The levels of plant, equipment and technology and continual updating in these relatively new, larger plants have enabled them to compete on the world stage for the last 20 or so years [2].

All foundries in Thailand currently face the worldwide problem of skill shortages at all levels from foundry operatives to technical management. Even in the large automotive foundries technical staff consist mainly of graduates in science or engineering, who may have limited understanding of foundry metallurgy and processes. Other than overcoming the “dirty, dusty and noisy smokestack image” the foundry industry is not a special case since across all sectors of industry in Thailand there is a shortage of science & technology based professionals with the problem being more widespread at the vocational level. Among the hurdles of globalization and competing on the world stage, coping with more stringent requirements from customers, introducing new technology and improving environmental performance the shortage of technical skills is perhaps the greatest threat to the continued development of the casting industry in Thailand.

III. A General View of The Sme Foundry Industry In Thailand

The SME casting producers are generally family run with one owner or partnership among relatives. Workers are generally unskilled to semi-skilled with low to medium levels of education. There are relatively few trained graduate-level engineers or foreman/supervisor level personnel with vocational diplomas. In some cases, management responsible for technical and quality matters may not hold any form of technological qualification. The low skill levels combined with the use of second-hand or rebuilt equipment, due to limited investment, result in a number of production and quality problems. Green sand and CO_2 processes are widely used for their ease and to minimize the cost of moulding but without appropriate control, even these basic processes can suffer from high levels of defects such as pin-holing, blowholes and burn on. Process control is limited and only final sampling inspection tends to be used, many problems only coming to light during subsequent machining by customers. Some foundries do monitor composition by spectrographic analysis but mechanical properties are usually assessed by hardness.

SME foundries can be innovative in re-engineering of second hand equipment and in reverse engineering but most production problem solving and methods engineering still follow trial and error routes. Costs management needs improvement. Small foundries tend to have only basic accounting systems that lack of detailed analysis of the total costs of fulfilling orders. This means that in general, managers do not often recognize the financial need to solve quality problems. They do not realize how much the inability to reduce defect and rework levels is costing. Likewise, some foundries are still giving insufficient attention to energy efficiency and environmental issues. Hence for this sector tackling quality problems, improving process control, and cleaning up their production processes are major steps that must be taken. There are however encouraging signs that second and third generation owners, who are technically trained, do see these problems and are improving the technology of their operations.

IV. Towards Improving Technical Performance And Quality.

Making castings is not as easy as it looks. Production is subject to many interacting variables that affect the behaviour of the various materials and processes used and hence the casting quality. A basic understanding of "why, how and when" materials & processes need to be monitored and controlled is essential even when relatively simple castings are being made – if they are to be produced without defects.

In consulting with foundries, not just in Thailand, one is often met with the response:

"We want the process to work! We do not want to know why it works and we do not want to spend money to find out why - or indeed make it work better! Anyway, we have not got the time or staff, and we can't afford to do any training, let alone get involved in any research or development!"

Managers are under pressure to maintain production so this may not be a fair view of foundries and management attitude. However, it does show that foundries, especially in the SME sector, need more encouragement, guidance and support in seeking to make technical improvements in their operations. In Thailand, there is still a need for better co-operation and interaction between industry and the university/government R&D centres.

In the past industry in Thailand has increased and improved production capabilities by importing mature technology from overseas. Hence industry, including metal casting, has yet to develop a "R&D culture". However, this should not discourage SME foundries from approaching the universities with their technical or other problems as potential topics for under-graduate or even post-graduate projects. Several universities have well established metallurgical & production engineering departments with metal melting & foundry facilities and advanced materials characterization equipment. There is now considerable research experience in cast metals in areas such as structure-properties relationships in casting alloys, heat treatment, simulation and modeling, semi-solid processing, etc. [3]. Likewise, MTEC - the National Metals & Materials Technology Centre has long term experience in R&D, consulting and training for the foundry sector with recent emphasis on high pressure die-casting, casting simulation, computer aided engineering and robotics. To stop firefighting and make real improvements SME foundries should make use of this proven research capability and seek assistance in examining and benchmarking their performance and in identifying, investigating and solving their most pressing problems.

Many small foundries face many very similar technical problems, e.g. cost effective use of charge materials, coping with high return greensand temperatures, storage deterioration of cores in high humidity, control of inoculation, etc. If there was a reliable database on casting production, via a foresight or revised master plan approach, in Thailand then such common problems could be more easily identified. Research capabilities and funding could then be more efficiently prioritized and used to make improvements for the overall well-being of the industry. Clearly this requires co-operation between competitor foundries – this has been normal for many years in Europe and the US, so there is no reason why it cannot happen in Thailand.

All parties, especially those that control the provision of research funding, should recognize that to be innovative, the research projects do not only involve design and development of new products but also the further development of existing processes by improving quality, efficiency and environmental aspects and by reducing costs. It is believed that optimization of existing processes offers real opportunities for improvements in the Thai SME metal castings sector.

Towards process optimization all foundries, both large and small, could make better use of tools and techniques such as FMEA and SPC to reduce variation in processes and improve quality and reliability. Even foundries showing compliance with certified quality management systems could make more use of the process and inspection data that is already being collected. Up to the present time, in the SME foundries little use has or is being made of SPC or indeed of any basic "cause & effect" analysis towards defect reduction. At very little cost the use of simple "fishbone" or "why-why" cause & effect exercises via informal brainstorming (not blamestorming) sessions can quickly point the way towards where improvements could be made and highlight variables where SPC could be used. Pareto analysis can be used to decide which problems are to be tackled first. It is worth noting that most resistance to SPC is from management with the shop floor being much more receptive once it is explained that the aim of SPC is to prevent defects. The shop floor has a first-hand view of scrap produced every day and know that any steps taken towards its reduction will increase their job security.

SPC can perhaps be most easily introduced into small foundries via attribute charts from inspection data and basic variable charts e.g. for critical dimensions (mean & range) or metal pouring temperature (reading-moving range) [4]. As a foundry gains more experience and confidence the cause & effects approach can become more detailed as design and process FMEA studies. Small foundries should also consider taking on university work experience students or provide some support for in-company postgraduate study to tackle process optimization projects through a Design of Experiments (DOE) Taguchi approach.

V. Involvemnet In The Complete Production Route

Where possible all foundries need to become involved in the design of a cast product and then after the casting has been produced they must understand and apply correct heat treatment, machining and any other required finishing operations such as surface treatments. If a foundry is not involved in the design process then they may be asked to produce a component having a shape and size for which it is very difficult or costly to produce a satisfactory casting. For example, consideration must be given to: shapes which are difficult to mould or require complex core-boxes or dies; designs with sharp changes in section thickness; designs which are difficult to fill correctly during pouring; designs with regions that are difficult to feed, etc. All these features must be considered with due regard to the nature of the alloy to be cast and the need for any subsequent heat treatment, dimensional control and machining operations. By making use of computer based process modeling and simulation all foundries can confidently solve the methods engineering problems in designing the gating and feeding system for a given casting. The casting can effectively be made on the computer to ensure correct design of any pattern equipment or tooling so that when the casting is made then it is “right first time”. The design, since made, could then be accumulated in a data base for subsequent use to minimize design lead time in the future.

The use of simulation offers considerable savings in time and production costs since yield (in the foundry sense) is optimized by avoiding oversized gating and feeding systems, whilst overall yield is improved by reduction in scrap caused by defects such as shrinkage, misruns, dross and inclusions in castings. SME foundries do not have to invest in simulation software but can make use of “bureau” services available in Thailand, for example at some universities, at MTEC and at companies such as M5 Engineering. All foundries should keep up to date with on-going simulation developments aimed at modeling and predicting events such as the occurrence of certain casting defects, residual stress patterns, microstructure and properties variations in different parts of a casting, effects of thermal treatments, flow of sand in core production, etc.

Pre-production work times can also be shortened by making use of rapid prototyping via additive manufacture. Additive Manufacturing (AM) via 3D Printing will also increasingly complement existing casting production technology since it offers faster routes into production, greater degrees of accuracy, reduced costs and less environmental impact [5]. For example, Fused Deposition Modelling (FDM) can build up polymers produce patterns for sand moulded castings with the advantages of time-saving and reduced costs when compared to conventional CNC machined Aluminium patterns. Where only one or two castings are required a pattern is not necessary. Sand moulds and cores and sand models of castings for prototyping can be produced directly from CAD data enabling pattern-less casting, reverse engineering, and customizing of cast parts. In particular, broken or worn out parts can be quickly replaced minimizing any downtime in the use of plant or equipment. One small company, Speed 3D Mold situated near Bangkok has already led the way in Thailand by investing in 3d scanning and binder jet 3d printing technology [5].

It is very important for the future of SME foundries that “bureau’ and training services in simulation, modeling, prototyping and additive manufacture be expanded to enable wider improvement in product and tooling/die design. High pressure diecasting is one area where modern production capacity has rapidly expanded in Thailand but where there is still very limited design capability.

energy and environmental issues.

Since the 1970s there have been ongoing initiatives in various industrialized nations to save energy and reduce waste in manufacturing industry especially in the castings production sector which is energy intensive. In the UK for example the Best Practice Programme run by the Energy Efficiency Office encouraged and provided information to foundries to make energy savings especially in metal melting and liquid metal handling which accounts for 60-70% of energy use in foundries. [6]. There are no current energy conservation and waste prevention schemes aimed at the foundry industry in Thailand. The large joint venture automotive foundries are up to world class standards with their environmental performance and energy usage but many of the SME foundries need to make significant improvements in both energy usage and environmental performance.

As in the case of energy conservation there has been no reported overall survey of environmental issues in Thai metal casting but initial attempts have been made to develop an indicator model to evaluate environmental impact from the “machinery” sectors [7].

A study in Europe has shown that foundries tended to underestimate their energy saving potential at 7.5% (on average) which is less than one third of the 25% saving estimated for the European industry in general. This study also concluded that the main drivers for improving energy efficiency were financial including the threat of rising energy prices and the availability of beneficial loans for investments to improve efficiency. There are several areas where savings can be made by Thai foundries particularly via quality improvements to reduce scrap and increasing casting yield. Experience shows that a typical aluminium foundry could save at least 20% of its energy costs without any major capital investment just by tightening up quality control and by good housekeeping [8].

Under the Industry 4.0 banner innovation is currently being promoted in Thailand. In SME Thai foundries and the metals industry in general, Industry 3.0 needs to be made much better by co-encouraging greater take up of best available technology (BAT) for energy efficiency. This together with practical process development projects via improved contact with universities and research centres will certainly improve overall technical capability and quality levels.

Thailand is not alone - in a United Nations Industrial Development Organization (UNIDO) project on sustainability across the Philippines, Indonesia, Vietnam and Thailand, the metals industry has been called a “growth with care” industry [9]. This study noted that many metal companies across the ASEAN region have inadequate understanding and practices in process control thus producing more scrap, more re-work, using more energy & other resources than they should and creating more waste. The study also observed that in the region there are many world-class companies using BAT in “green” production practice, and that the knowledge and experience in such companies could be used by government organizations to help support training & education for the technical development of local industry. This is especially relevant in Thailand where SME foundries could improve their performance by learning from the approaches to production & process control in the modern casting plants of the automotive sector. In SMEs obtaining suitable investment is always the major obstacle but that should not be an excuse for not making energy savings by not using basic process controls and not having good housekeeping on the shop floor. For example, correct storage of charge materials in iron and steel foundries to avoid contamination and mix-up of ferroalloys and especially avoiding the charging of wet and oily steel scrap into induction furnaces just requires common sense.

SME foundries not only need help in setting up effective process controls, reducing defects and improving energy efficiency but also in improving environmental performance – notably noise, dust and emissions control and the disposal of wastes. SME foundries have very limited knowledge of pollution control or Environmental Management Systems (EMS) and many seem to be unaware of the dangers posed by the raw materials that they use, e.g. resins and binders, and by the emissions and waste from their processes. It is of concern that most small foundries do not have product data sheets for consumables such as fluxes, treatment alloys, binders, coatings, etc. available. Insufficient knowledge about the materials that are being used has serious safety implications. Foundries must demand complete safety information about their raw materials from their suppliers. They must also ensure that shop floor personnel receive correct training in the safe handling, storage and use of materials such as melt additives, exothermics, resins, coatings, etc. In many small foundries safety equipment such as eye and ear protection is often not being used. Also, many workers do not have adequate footwear protection. Safety wear is said to be available but its use is clearly not being enforced. Many of the smaller foundries have poor storage arrangements, poor lighting, and bad-housekeeping in general. These problems can be tackled at relatively low cost and by improving shop floor discipline.

In metal casting across the world processes such as melting, pouring, mould & core production, knock-out and cleaning will continue to be affected by on-going Environmental Legislation, especially in Europe and the US. Worldwide it is accepted that future developments should be “sustainable”. In moving towards clean and economic use of resources, all foundries must develop Energy and Environmental Management schemes and minimize waste.

All foundries face similar “waste” disposal problems, for example:

- Spent greensand or chemically bonded sands such as CO_2-Silicate, Shell, Hot-box, etc.
- Sludge or dry residue from wet scrubber or dry bag filter systems
- Drosses from melting and metal treatment.

It is almost impossible for small foundries to tackle such problems alone. The problems can only be addressed on an industry wide basis such as that used both in the US and UK. There is a need for the Thai casting industry as a whole to examine sand reclamation, applications for spent foundry sand, and the recovery of metal from dross. At present, much of this valuable “by-product” goes to uncontrolled landfill to pose future environmental threats from leaching into soils and watercourses.

The foundry industry as a whole across ASEAN could address these problems and seek to provide clear information and practical advice to SME foundries on how to save energy, how to make better use of waste such spent sand and slag, and especially how to be cleaner and safer.

VI. Equipment, materials and processes.

Existing plant and equipment needs to be updated and improved e.g. by the use of sensor technology in burner control in particular, and in automatic control in general. Modernization of melting equipment, moulding lines, knockout and fettling areas with improved fume & dust extraction requires considerable investment. At lower costs, the performance of older plant & equipment can be improved by making use of condition monitoring and by ensuring that timely & correct maintenance is carried out. This will give better reliability and reduced variation in performance. There is considerable scope for the use of robots in foundries, for example pick and place in mould production, handling and pouring molten metal, and automated high pressure die-casting [10]

Much more attention must be given to mould and core-making practices. Most mould related problems are due to the poor state of maintenance of mixing and moulding plant and limitations in sand control. Many foundries continue to use damaged poorly fitting moulding boxes such that flash, mismatch, sand inclusions, and other defects due to mould damage are very frequently found in castings. The provision of correctly matching boxes and box pins is vital if castings are to be made with greater dimensional accuracy, less machining allowance and to more complex designs.

A large volume of FC and FCD Iron automotive castings are produced in Thailand, as elsewhere greensand moulding, i.e. the use of clay bonded sands, is employed., Ambient temperatures are relatively high in Thailand so all foundries, both large and small, experience mould related defects caused by the excessive high temperature (above 50°C) of sand returning to the mill in greensand plants. As production levels have increased in some foundries they have tended to outpace sand plant capacity such that system sand in storage hoppers does not have sufficient time to cool. Hence there is need for better production planning & scheduling to reduce the demands on the existing sand plant, for the use of improved sand cooling mechanisms and for regular hopper maintenance. There is also the R&D challenge to develop bentonite clays whose bonding properties are less sensitive to higher temperatures.

There are still some basic problems to be tackled when using chemically bonded sands. Simple process controls such as control of gassing time and rate in the CO2-silicate process, and control of temperatures and times in Shell moulding are not being used. Such lack of control gives under or over-cured moulds or cores and guarantees casting defects. The solution is quite simple – correct work instructions and training of operators. Most foundries are also unaware that stored cores can deteriorate very quickly in the high humidity conditions, especially in the wet season. Foundries are encouraged to do their own practical testing to determine the maximum safe storage time of each type of core, and then control core production accordingly.

Another area of common problems in most iron foundries is that of consistent melt treatment and inoculation in producing FC and FCD irons. Many SME foundries do not make effective use of melt conditioning and also tend to not only use too much of the wrong type of inoculant but also use it incorrectly. There is a need for correct application of ladle and in-stream inoculation procedures. There are particular problems still to be overcome in the inoculation of the very low Sulphur content FC iron produced as a result of steel scrap based charges. To assist iron foundries, there is considerable opportunity for practical research into the combined influences of charge materials, notably the presence of Ti containing and Zn coated steel scrap which is now in common supply, inoculation and other variables on microstructures and machinability, especially with regard to the quality of machined surface finish.

Many small foundries have tried to cut their costs of imported supplies by making use of raw materials and spare parts from less expensive overseas or home-based sources. This can and has given rise to quality problems due to the lack of suitability and consistency of some of these materials or parts. The application of "cheaper" raw materials needs to be more carefully considered and monitored, since the use of any sub-standard material can lead to higher reject costs which will far outweigh the raw material savings. Clearly there is a need for research into local materials such as alloying/treatment additions, sands, binders and refractories, etc. so that they can all be used in a cost-effective way without compromising quality.

Looking to the future, cast iron parts have long been subject to replacement by light alloys. At present pressure diecasting of Al alloys for motor cycle and computer parts is well established here but there is limited capability for sand and gravity Al castings, and no experience with Mg based alloys. In Al castings for cylinder blocks non-turbulent controlled mould filling technology as in the Cosworth (cold set zircon core assembly) and the later Gemini (box-less greensand) processes has set new standards for clean, consistent, accurate sand castings. Both systems use electromagnetic pumping to ensure non-turbulent filling to avoid oxide film and bubble damage in castings. Such processes or similar are not yet being used in Thai foundries. Correct mould filling, its simulation, system design and control are key areas for developments in Al alloy casting production by both sand and die casting processes and are also important in producing other alloys, e.g. alloy ductile iron exhaust manifolds. Foundries also need to look at the market for castings for application in electric powered vehicles including light alloy body parts.

Thai research in Al diecasting includes the relatively new techniques of Semi-Solid- Metal forming (SSM) – thixocasting, rheocasting and squeeze casting and the production of metal matrix composites as castings. SSM and single shot melting offer Thai foundries the potential for considerable energy savings coupled with easily automated, high-rate production of high integrity, near net shape components having fine, uniform microstructures with enhanced mechanical properties.

In meeting competition from light alloys, iron founders will have to develop the ability to produce thinner walled castings to save weight – this will require improvements in both dimensional control of moulds and cores and in melt conditioning & inoculation treatments to obtain correct microstructures at relatively high cooling rates. Worldwide in the automotive sector, for improved mechanical properties compacted graphite irons (CGI) are replacing conventional grey iron FC grades, e.g. for engine blocks, and austempering is being more widely used to heat treat ductile irons, e.g. for truck wheel hubs.

Hence scope for widening the range of cast alloys in general include:

The introduction of compacted graphite irons and austempered ductile iron into the automotive and general engineering sectors

Magnesium based castings for auto-parts and electronics

Improved production of corrosion and heat resisting steels

Special alloys for use in power generation such as Ni-base

VII. Summary.

If the 2021 vision in the Thailand Automotive Industry Master Plan (2012-2016) which specified that, "Thailand is a global green automotive production base with strong domestic supply chains which create high value added for the country", is to be achieved then the Thai SME foundries and die-casters in the automotive sector need to continue to improve all aspects of their operations. The continued success of Thai foundries in all sectors depends on maintaining and improving delivery of cast components which, against all forms of competitive sources and processes, satisfy the increasingly more demanding requirements from customers. These demands are for higher quality and reliability, for increased dimensional control, for improved casting alloy performance, for thinner walled castings and weight savings, and for shorter lead times, etc. As well as achieving these improvements foundries must also respond to the "costs down" approach of customers, especially those in the automotive industry, and to clean up their processes to comply with ever increasingly environmental legislation.

SME foundry companies in Thailand have a "Can do" mentality – this is encouraging. However, for survival in a tough marketplace this attitude must become "Can do correctly, efficiently, consistently, cleanly and safely"

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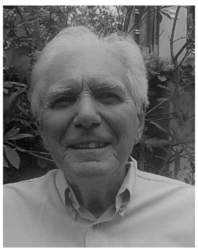

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