# The forty years of vermicular graphite cast iron development in China (Part Ⅰ)

**QIU han-quan**[1] and **CHEN Zheng-de**[2]
(1. Shandong institute of mechanical design and research; 2. Shanghai office of UK Vantage Co.)

**Abstract:** In China, the research and development of vermicular graphite cast iron (VGCI) as a new type of engineering material, were started in the same period as in other developed countries; however, its actual industrial application was even earlier. In China, the deep and intensive studies on VGCI began as early as the 1960s. According to the incomplete statistics to date, more than 600 papers on VGCI have been published by Chinese researchers and scholars at national and international conferences, and in technical journals. More than ten types of production methods and more than thirty types of treatment alloy have been studied. Formulae for calculating the critical addition of treatment alloy required to produce VGCI have been put forward, and mechanisms for explaining the formation of dross during treatment were brought forward. The casting properties, metallographic structure, mechanical and physical properties and machining performance of VGCI, as well as the relationships between them, have all been studied in detail. The Chinese Standards for VGCI and VGCI metallographic structure have been issued. In China, the primary crystallization of VGCI has been studied by many researchers and scholars. The properties of VGCI can be improved by heat treatment and addition of alloying elements enabling its applications to be further expanded. Hundreds of kinds of VGCI castings have been produced and used in vehicles, engines, mining equipment, metallurgical products serviced under alternating thermal load, machinery, hydraulic components, textile machine parts and military applications. The heaviest VGCI casting produced is 38 tons and the lightest is only 1 kg. Currently, the annual production of the VGCI in China is about 200 000 tons. The majority of castings are made from cupola iron without pre-treatment, however, they are also produced from electric furnaces and by duplex melting from cupola-electric furnaces or blast furnace-electric furnace. Examples of typical applications for VGCI castings are introduced in this paper. In China, the technologies such as rapid testing of the molten metal and non-destructive testing of casting microstructure still need to be improved. Several proposals are put forward in this paper in order to improve the production of VGCI. Generally speaking, in China, the research, production, and application of vermicular graphite cast iron are at the same level as in other developed countries and in some fields China even takes lead. (332 references and 5 Tables)

**Key words:** vermicular graphite cast iron; China; review
**CLC numbers:** TG143.5/-1 **Document Code:** A **Article ID:** 1672-6421 (2007) 02-091-08

## 1. Brief introduction to VGCI development in China

The earliest report on vermicular graphite (VG), was in Morrogh's paper in 1948. He found 'thick flake graphite' (i.e. vermicular graphite), during his study of spheriodal graphite cast iron (SGCI), treated with cerium. However at that time VG was considered a failure with no practical application. The breakthrough for VGCI was made in the 1960s: R. D. Shelleng of the American International Nickel Co. obtained a British patent (1069058) and an American patent (3421886) for the production of VGCI using magnesium-titanium alloy; later, Austrian W. Thury et al, obtained an Austrian patent (290592) for the production of VGCI using mischmetal. In 1976, with an improved formula developed by BCIRA, the American International Nickel Co. produced and marketed 'Foote' alloy; since then VGCI has been developed relatively quickly [1-4].

In China, knowledge of VG also occurred with the production of SGCI, especially in the early 1960s, when SGCI was made using Rare Earth (RE) ferrosilicon alloy, and vermicular graphite appeared quite often. As in other foreign countries, this type of graphite was considered as a 'black spots' defect in China. Mr QIU Han-quan of the Shandong Institute of Mechanical Design and Research deliberately studied iron containing this kind of graphite as a new type of engineering material. From 1965, he treated liquid iron with RE alloy and used the resulting iron to replace high strength GCI in Jinan's Materials Test Machinery Plant and Jinan's Machine Tool Foundry [5, 6].

Nevertheless, in China VGCI was not developed from bad SG iron, but due to the following two factors:

(1) Early in 1965, when the authors added RE alloy to high

1 Mr. QIU Han-quan, born in 1937 in Xiamen city, is an outstanding expert with special government allowance, retired; he graduated from Shangdong University in 1960, and then teached in the university; from 1963 he worked in the Shandong Institute of Mechanical Design and Research and engaged in the research on VGCI for long time, particularly did practical research in many foundies. E-mail: qiuhanquan88@hotmail.com.
2 Mr. CHEN Zheng-de, senior engineer, was born on 1946 in Shanghai, graduated from Shanghai University of Science and Technology in 1970, worked in foundry for some years, from the early of 1980 worked in Shandong academy, participated in the experiment, production and application of VGCI since 1970; now he is the manager of Shanghai office of UK Vantage Co; E-mail: chenkevin@126.com

carbon liquid iron, it was found that some 'black spot' occurred in the fracture of samples and the tensile strength of the iron exceeded grade 300 GCI. At that time, due to the shortage of scrap steel, using RE to directly treat cupola iron without the addition of scrap steel to obtain high grade GCI, became important.

(2) From 1967, considering the beneficial effect of RE in treating steels and the shortage of scrap steel supply in China, some foundries making machine tool castings tried to add RE alloy into high carbon molten iron to obtain high grade GCI. During these experiments it was found that the iron with vermicular graphite had high strength; thus high strength GCI was obtained without the addition of scrap steel [8, 9].

Since the above high strength GCI was obtained using RE alloy, it was called RE high strength GCI [9], RE high grade GCI [10], RE 40-68 GCI [11], RE GCI [8,12], RE 'thick flake graphite' GCI [14,15], and compacted graphite iron [16,17] etc. At the end of 1970s, according to the two-dimentional morphology of the grahite, this iron was called vermicular graphite cast iron (VGCI) in the national and international literature [18]. In 1979, at the national conference on RE, the author suggested that vermicular graphite cast iron was called VCGI for short [19].

During research, the author found that for flake graphite to change to vermicular graphite, there is a critical addition of RE; above this critical addition the mechanical properties will change significantly. An equation for the critical addition was formulated and Tables 1 and 2 list the critical addition based on this equation [10,11,20]. This addition rate was utilized for stable production of VGCI in China.

**Table 1 The critical treatment alloy addition for obtaining VGCI, wt.%**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Base metal sulphur | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 |
| Calculated pure RE addition | 0.176 | 0.210 | 0.246 | 0.280 | 0.315 | 0.35 | 0.384 | 0.424 | 0.482 |
| Equivalent addition of RE ferrosilicon | 0.82 | 0.98 | 1.14 | 1.31 | 1.47 | 1.63 | 1.79 | 1.97 | 2.15 |

**Table 2 The critical treatment alloy addition for obtaining VGCI, for electric furnaces, wt.%**

| | | | | | |
|---|---|---|---|---|---|
| Base metal sulphur | 0.012-0.016 | 0.016-0.020 | 0.020-0.023 | 0.023-0.025 | 0.025-0.029 |
| Addition of RE ferrosilicon | 0.66-0.74 | 0.74-0.81 | 0.81-0.86 | 0.86-0.90 | 0.90-0.98 |

* The above two tables are based on approximately 21.5 % RE content and should be taken only as a reference for different melting conditions.

Similar to SG iron production, a large amount of dross is formed after treatment of VGCI. This became one of obstacles for expanding the application of VGCI. The author published a paper on formation mechanism of the dross [21]. Based on the mechanism RE-zinc-alloy was invented and the dross problem was solved; other methods based on these principle also produced good results.

It is seen that in China, the research, development and application of VGCI were started in the same period as in other developed countries, but its actual industrial applications were even earlier than in other countries. This was demonstrated from the appraisal conclusion on the research program of the fifth 5-year plan: 'Making VGCI using cupola iron' carried out by the Shandong Institute of Mechanical Design and Research and Shandong Material Test Machinery; the appraisal meeting was organized by the first Ministry of Mechanical Engineering of China and held on December 11, 1980.

Since mid 1960s in China, intensive research and study have been carried out by universities, research institutes and companies, including the study of microstructure, physical properties, service performance, casting properties, testing and inspection, machining, welding, heat treatment, electro-plating etc. Chinese Ministry Standards: 'Standard of Microstructure of Vermicular Graphite Cast Iron (JB/T 3829-84') and 'Standard of Vermicular Graphite Cast Iron (B 4403-87') were issued in 1984 and 1987 respectively and revised in 1999. In addition, the 'VGCI Standard of Chinese Ministry of Railway (TB/T 2444-93)' was also issued in the 1990s, for applications in the railway industry. The Collection of Chinese Vermicular Graphite Cast Iron Papers, edited in 1987, contains more than 351 technical papers [22]. After completing the research projects on VGCI in the national fifth, sixth and the seventh 5-year plan, the research and application of VGCI have been further developed. Generally speaking in China, the research, production, and application of VGCI are at the same level as in other developed countries; in some fields China even takes the lead.

Between the late 1960s and late 1980s, VGCI was used in small volume production trials for hydraulic components in milling machine M114, universal milling machine M131W [10, 23, 24], internal grinder M210 and external grinder M211[25]; it also replaced the high grade GCI in lathes CM6125, C616, C620 and C630 [26-28], slotter B5032 [8], double-housing planer B2010A, press JA31-315 [12], double housing planer B2152 and slotter Y58 [9], 160 t horizontal borer [28, 29], medium and large hydraulic presses [30]. In addition VGCI was used in thin wall castings for engines; for example, the engine cylinder block and head, fly-wheel, connecting plate, cylinder liner etc [31-33]. Good results were also obtained using VGCI for butterfly valves, scrapers in sand mixer, rolls of sand mills and paper machines [17,34,35]. The application of VGCI was expanded to more than 200 components from more than 60 manufacturers in various industries including machinery manufacturing, mining, metallurgical, transportation, light industry, textile and defense industries and showed very good technological and economical results. The heaviest vermicular graphite iron casting produced is 38 tons [9], and the lightest is only 1 kg [20]. Most of the VGCI was made directly from cupola iron with a small amount made from electric furnace or duplex melting of cupola-electric furnace; a small number of VGCI castings were even made directly from blast furnace iron.

After more than twenty years study and application, experience and expertise have been accumulated for producing

VGCI, especially using cupola melted poor quality iron. Some of them have been written and included in the university text books. There is a separate chapter of VGCI in the Chinese 'Cast Iron Handbook' and other manuals [36-40].

In the last ten years, due to rapid economic development, the increased high demand for engines and metallurgical equipment castings, normal grey cast iron (GCI) can not satisfy the requirement of the development; while VGCI shows the special advantages and has been developed very fast. Currently in China the production of VGCI is about 200 000 tons. Nevertheless some problems still exist and influence the development of VGCI.

However the enhancment and development of VGCI have been influenced in China due to following reasons:

(1) Due to lack of knowledge and understanding of the advantages, VGCI is still considered as a solution only for solving the shortage of steel scrap. Therefore the production of VGCI is sensitive to the supply of scrap steel.

(2) In China, generally the good quality of raw materials is very difficult to ensure (this is a key problem), the melting furnaces are simple, and the quality of liquid iron is poor (low temperature and high and inconsistent sulphur content); production sites are lack of quick, accurate test and control measures. All these result in inconsistency of VGCI production, especially, it is very difficult to accurately control the high percentage of vermicular graphite (>90%) obtained in thin wall castings.

In recent years the application of VGCI in Europe and North America has developed very rapidly. VGCI as a new engineering material has been used in safety critical castings, for example engine blocks. The draft European standard for VGCI has been completed and the formal standard will be issued later this year. In this standard, the percentage of VG should be > 80% in main wall sections of the casting; in other sections VG can be lower than 80%. No flake graphite is allowed in any section of the casting. In Sweden, for obtaining the special properties in the piston rings, the minimum VG specified is >90%. From 2003, USA has separated the production of VGCI from that of SG iron.

The more rapid development of VGCI in western countries is due to the higher and higher requirements for powertrain and parts for the automotive industry. As the special power ratio (kW/litre) of engines becomes higher and higher, the operating temperature becomes higher and higher. Aluminium alloy cannot withstand the increased loads and VGCI is the best solution to the problem; VGCI has strength close to SG iron, damping capacity, thermal conductivity and casting properties are all similar to GCI; plasticity and thermal fatigue are much better than GCI. The weight per unit power of a VGCI engine is lower than that of an aluminium engine. In addition, the production process from metal ore to finished casting, the energy consumption of VGCI is less than that of aluminium. All this promotes the development of VGCI [4].

In China, it can be seen that although rapid development in the production of VGCI has occurred, the gap in the percentage control of VG and standards between China and other developed countries is large. This needs attention for Chinese foundrymen and scholars.

**(Note: the Part II and Part III of the paper will be published in No.3 and No.4, respectively )**

## References


[1] QIU Han-quan. Review on national and international vermicular graphite cat iron. Foundry, 1979, 28(4):29-38, 48. (in Chinese)
[2] Stefanescu D M, C R Loper, Jr. Neue Fortschritte auf dem Gebietdes GuBeisens mit Vermicular Graphite. GieBerei-Praxis, No.5.10Marz, 1981, S. 73-96.
[3] HE Zui-zhi. Introduction of National and International Development and Application of Vermicular Graphite Cast Iron. Chongqing, China: Science and Technology Literature Press, 1979:3-19. (in Chinese)
[4] HUANG Hui-song, SHENG Da and ZENG Da-ben. Vermicular Graphite Cast Iron. Beijing China: Tsinghua University Press, 1982(12):1-3. (in Chinese)
[5] QIU Han-quan. Making high strength grey cast iron using pig iron without scrap steel. Shandong Machinery Bulletin, 1966 (2) :11-12, 10. (in Chinese)
[6] YU Hua-shun. Technology and process for producing vermicular graphite cast iron. Modern Cast Iron, 2002(3):40-43. (in Chinese)
[7] QIU Han-quan and JIANG Yi-jian. Effect of Rare Earth on Malleable Iron. Proceedings of Annual Conference of Institute of Shangdong Machinery, (Experience exchange of rare earth application organised by Ministries of the First and Eighth Mechanical Industry), August 1965: 22-29. (in Chinese)
[8] LI Hui and GONG Shuo-ru. A summery of rare earth grey iron production. (Domestic exchange) June 1967. (in Chinese)
[9] PENG Ti-yuan et al. Application of rare earth grey iron in heavy machine tool. Foundry, 1971(2):17-23. (in Chinese)
[10] QIU Han-quan and ZHANG Shi-dao. Rare Earth High Grade Grey Iron. Shangdong Province Casting Experience Exchanges. October, 1966. (in Chinese)
[11] QIU Han-quan. Make high quality cast iron - Introduction to rare earth grey iron grade 400. Foundry Equipment, 1971(3):31-41. (in Chinese)
[12] GUO Xi-nan et al. Summery of rare earth grey iron experiment. Shandong Machinery Bulletin, 1968(5):1-24. (in Chinese)
[13] ZHANG Lin-shan et al. Experiment on rare earth grey iron and design revolution. Shandong Machinery Bulletin, 1968(5):36-46. (in Chinese)
[14] LI Long-cheng. Summery on rare earth thick flake graphite iron experiments (domestic exchange). November 1975. (in Chinese)
[15] YING Zhong-tang. Study on casting process of 300 series diesel engine piston rings and rare earth thick flake graphite iron (Domestic exchange). August 1979. (in 'Chinese)
[16] ZHOU Qing-de and SU Jun-yi. The Growth of Compacted Graphite. Proceedings of First National Conference on Primary Solidification of Compacted Graphite Cast Iron, January 1981. (in Chinese)
[17] XU Zhen-yuan et al. Application of compacted graphite iron in coupling box castings. North China Valve, 1980(1):2-9. (in Chinese)
[18] HE Zuo-zhi et al. Vermicular graphite iron - application study of rare earth calcium in cast iron. (Domestic exchange), February 1979. (in Chinese)
[19] QIU Han-quan. Study and application of rare earth vermicular graphite iron. Shandong Machinery, 1979 (4). (in Chinese)
[20] QIU Han-quan. A new rare earth copper cast iron piston ring material. Modern Cast Iron, 1982 (3). (in Chinese)
[21] QIU Han-quan. Study on new vermiculaisers for vermicular graphite iron. Ductile Iron, 1980(2) and Materials for Mechanical Engineering, 1981(1):15-20. (in Chinese)
[22] Collections of Chinese vermicular graphite iron literature, edited by Yu Jin-xin (Domestic exchange), April 1987. (in Chinese)
[23] ZHANG Shi-dao. Replacing scrap steel using rare earth to produce high grade grey iron. Shandong Conference on Expanding the Application of Rare Earth. February 1968. (in Chinese)
[24] QIU Han-quan et al. Summary of experiment on medium phosphorous rare earth wear resistant cast iron. Foundry, 1971, 20(2):10-16. (in Chinese)
[25] Chengdu Machine Tool Plant, Institute of Technology of Chengdu, Sichuan Institute of Machinery and Design. Production of machine tool castings using Vi-Ti pig iron. Foundry, 1971, 20(6):34. (in Chinese)
[26] QIAN Yu-xian. Experiment on machine tool production using rare earth grey iron. Machine Tool Technology Communications (Special edition Foundry) 1973 (4); Technology Exchange, edited by

Shandong Institute of Machinery and Design, 1974(1-2):89-103. (in Chinese)
[27] QIU Han-quan. Rare earth application in machine tool casting. Conference of Experience Exchange on Rare Earth Application in Machine Tool, organised by Bureau of Machinery and Electrics Changwei Area. Technology Exchange, 1970(3):56. (in Chinese)
[28] DING Yuan-qing. Rare earth high grade grey iron. Foundry, 1971, 20 (1):16-22. (in Chinese)
[29] DING Yuan-qing. Summary of Application of Rare Earth High Grade Grey Iron 400 in Boring Machine. Shandong Conference of Casting Experience Exchange. May, 1973. (in Chinese)
[30] HUANG Peng-xiang et al. Experimental study on vermicular graphite iron in large and medium oil presses. August, 1981. (in Chinese)
[31] QIU Han-quan. Application of rare earth high grade grey iron in thin wall castings. Technology Exchange, 1970(3):54-55. (in Chinese)
[32] WANG Yi-bin. Application of Rare Earth Grey Iron in 496 Diesel Engine. Shandong Conference of Casting Experience Exchange. May 1973. (in Chinese)
[33] CHEN Tong-sheng. Production of cylinder rings using rare earth grey iron. Foundry, 1972(5):36-38. (in Chinese)
[34] LI Xiao-gao. Scraper in sand mixer made by rare earth Vi-Ti grey iron. Foundry,1975(3):48. (in Chinese)
[35] Application of Rare Earth in Grey Iron (edited by QIU Han-quan). Jinan Shandong: Shandong People Publishing House, 1973, 2:38-42. (in Chinese)
[36] Rare Earth Grey Iron and Cast Iron (edited by Foundry Division of Shanghai Institute of Technology). Shanghai: Shanghai People' Publishing House, December 1975. (in Chinese)
[37] Rare Earth High Grade Iron, Cast Iron and Melting (edited by six universities in north east of China). Beijing: Metallurgical Industry Press, November 1978. (in Chinese)
[38] Rare Earth Grey Iron and Cast Alloy and Melting, edited by ZHAO Jian-kang. China Machine Press, January 1979. (in Chinese)
[39] Vermicular Graphite Cast Iron, Chapter seven of Cast Iron and Melting, edited by LU Wen-hua. Beijing: China Machine Press, April 1981. (in Chinese)
[40] HUANG Shi-min. Ductile Iron, Compacted Iron and Heat Treatment. December 1983. (in Chinese)
[41] ZHANG Bo-min. Newest development of compacted graphite cast iron. Foundry, 2004, 53(5):7-10. (in Chinese)
[42] QIU Han-quan et al. Study on Control System of Consistent Production of Vermicular Graphite Iron. Appraisal document of seventh national development project (2). Proceedings of National Foundry Conference. October 1988. (in Chinese)
[43] SUN Yao-zeng. Rare Earth Vermicular Graphite Iron and Stable Production Process. First Anneal Conference of Shangdong Institute of Military Industry, March 1984. (in Chinese)
[44] HE Zhuo-zhi et al. Rare Earth Calcium High Grade Grey Iron-New Hydraulic Material. (Appraisal document). December 1978. (in Chinese)
[45] PENG Ti-yuan et al. Application of rare earth vermicular graphite iron in heavy machine tool. Ductile Iron, 1984(1):26-32. (in Chinese)
[46] QI Meng-diao et al. A study of the productive stability of vermicular graphite iron. Journal of Changchun University of Technology (Natural Science Edition), 1984(1):81-91. (in Chinese)
[47] FAN Xu-chu et al. New process for vermicular graphite iron- stirring on bottom of ladle. Foundry Technology, 1981(1):18-23. (in Chinese)
[48] WANG Hu et al. Summary of study on vermicular graphite iron gear box of rail vehicle. Foundry technology, 1984(2). (in Chinese)
[49] LU Hao-bing et al. Study on L 207E series diesel engine vermicular graphite iron piston rings. Locomotive & Rolling Stock Technology, 1983(2):7-16. (in Chinese)
[50] JIANG Bing-huan et al. Application of rare earth vermicular graphite iron in beam of double housing milling machine (Appraisal document), November 1982. (in Chinese)
[51] CHENG Xiu-di et al. Study and application of rare earth Mg-Ti vermicular graphite iron. Automotive Technology, 1981(6-7):38-43, 46-51. (in Chinese)
[52] CHEN Mian-ji et al. Study on rare earth vermicular graphite iron exhaust manifolds and the stable line-production. National Symposium of Rare Earth Application in Cast Iron. 1982. (in Chinese)
[53] SU Ying-long et al. Production of vermicular graphite iron gears using cupola iron. Ductile Iron, 1983(1):27-30. (in Chinese)
[54] QIU Han-quan et al. Experimental study on new process for vermicular graphite iron using cupola iron. Foundry, 1981,30(3): 8-11. (in Chinese)
[55] QIU Han-quan et al. Steel ingot mould made by vermicular graphite iron using rare earth zinc vermiculariser. Shandong Machinery, 1984(2). (in Chinese)
[56] GENG Zheng-he et al. Study on rare earth Ma-Ca vermicular graphite iron. Foundry Technology, 1982(3):33-38. (in Chinese)
[57] LI Yan-zhi et al. Study and application of vermicular graphite iron cylinder heads. Foundry, 1981,30(3):30, 7. (in Chinese)
[58] CHEN Xing-ying et al. Preparation and application of vermicular graphite iron. Modern Cast Iron, 1985(1):12-17. (in Chinese)
[59] ZHU Zheng-yu et al. A study on using cored-wire injection process to produce vermicular cast iron. Modern Cast Iron, 2003(3):27-30. (in Chinese)
[60] ZHU Zheng-yu et al. Study on cored-wire injection vermicularizing process for vermicular graphite cast iron production. Foundry Technology, 2004(10):28-31
[61] ZHU Zheng-yu et al. Development and application of vermicularizing alloys used in the cored-wire injection process. Foundry, 2005,54(1):61-64. (in Chinese)
[62] ZHU Shi-zhen et al. Study and application of small to medium vermicular graphite iron steel ingot moulds. Ductile Iron, 1982 (3):12-19. (in Chinese)
[63] WANG Xin-lei et al. Application of tundish ladle in production of vermicular graphite iron. Ductile Iron, 1988(3):34-35. (in Chinese)
[64] ZHANG Zhong-qiu et al. Heavy section vermicular graphite iron castings made by rare earth ferrosilicon. National Symposium of Rare Earth Application in Cast Iron. 1982. (in Chinese)
[65] PAN Zhong-yue. Process experiment of vermicular graphite iron by injecting vermiculariser powder. Guangzhong Technology, 1983(4). (in Chinese)
[66] CHAO C G , LU wen-hua, Wallace J F. Effect of treatment alloys and section size on the compacted graphite structures produced by the in-mold process. Foundry, 1984,33(6):13-20. (in Chinese)
[67] YING Zhong-tang et al. Ladle treatment of rare earth Mg ductile iron. Technology Reports, 1967 (1). (in Chinese)
[68] HUANG Xiang-peng et al. The relationship between structure and property of rare earth Mg-Ca cast iron and its control. Ductile Iron, 1980(4) (in Chinese)
[69] LOU En-xian. Effect of inoculation on production of vermicular graphite iron. Foundry, 1981,30(1):16-21. (in Chinese)
[70] DING Sen. Experimental study on vermicular graphite iron. Shandong Metallurgy, 1983(1). (in Chinese)
[71] ZHOU Ying-na et al. Heave section vermicular graphite iron rolls in cane mill. Ductile Iron, 1982(4):25-28. (in Chinese)
[72] ZHANG Zhi-shan. Study on process, structure and property of rare earth Si-Ca vermicular graphite iron. Thermal processing, 1981(6). (in Chinese)
[73] ZHANG Fu-quan et al. Rare earth combined treatment process of vermicular graphite iron. New Technology & New Process, 1997(3):25-26. (in Chinese)
[74] QIU Han-quan et al. Experimental Study on New rare Earth Vermiculariser. The Fifth National Annual Cconference of FICMES, 1982. (in Chinese)
[75] QIU Han-quan. Selection and Practice of Vermicularisers. Proceedings of Beijing International Foundry Congress, 1986. (in Chinese)
[76] ZHANG Zhong-qiu et al. Study of modification effects of rare earths and magnesium on cat iron. New Technology & New Process, 1997 (3):25-26. (in Chinese)
[77] SHEN Ze-ji et al. Vermicularising effect of single rare earth element. Foundry, 1983,32(6):19-25. (in Chinese)
[78] XU Han-fan. Summery of Experiment of Vermicular Graphite Iron Made by 60kW Induction Furnace (Domestic exchange), March 1980. (in Chinese)
[79] ZENG Da-ben et al. Study on modification effect of new rare earth Mg-Ti vermiculariser in preparing rare earth vermicular iron. Science Report of Tsinghua University, QH81026 (NO.98) July 1981. (in Chinese)
[80] LI Long-cheng et al. Effects of trace elements on modification treatment of vermicular graphite iron. The First Symposium of Cast Iron and Melting of FICMES, July 1979. (in Chinese)
[81] SU Ying-long et al. Laboratory study on vermicular graphite iron made under high sulphur iron (Domestic exchange), October 1979. (in Chinese)
[82] LI Qiu-shu et al. Study of the effects of Ti on the compacted graphite range of RE-Mg alloy. Journal of Taiyuan Heavy Machinery Institute, 1990(4). (in Chinese)
[83] LI Qiu-shu et al. Discussion on Ti, its existing status and effect mechanism in vermicular graphite iron. Journal of Taiyuan Heavy Machinery Institute, 1990(4):70-77. (in Chinese)
[84] LOU En-xian et al. Study on vermiculariser without Ti. Foundry, 1983,32(3):22-31. (in Chinese)
[85] YU Hua-shun et al. A study on aluminium vermicular graphite cast irons. Modern Cast Iron, 1996(2):25-27. (in Chinese)
[86] YU Hua-shun et al. The effect of aluminium on vermiculizing fadding resistance of CG iron. Foundry Technology, 1996(2):10-12. (in Chinese)
[87] YU Hua-shun et al. Study on effect of aluminium on structure and property of low silicon rare earth vermicular graphite iron. Foundry Technology, 1996(4):40-44. (in Chinese)
[88] YANG Xiang-shou et al. The effect of SG on the compacted range of graphite in thin section castings of C/V cast iron. Modern Cast

Iron, 1988(3):56-57. (in Chinese)
[89] XU Jin-cheng et al. Effect of trace elements on residual rare earth content in rare earth vermicular graphite iron. Foundry, 1993(4): 30-34. (in Chinese)
[90] XU Jin-cheng et al. Study and preparation of rare earth Mg-Cu vermiculariser. Chinese Rare Earth, 1996(1):37-41. (in Chinese)
[91] WANG Liang-yang et al. Effect of trace element pb on graphite morphology in vermicular graphite cast iron. Modern Cast Iron, 1993(1):17-21. (in Chinese)
[92] WANG Liang-yang et al. Vermicular graphite cast iron made from pig iron containing rich tin, arsenic and lead. Foundry, 1985,34 (5):20-26. (in Chinese)
[93] JI Wei et al. Effects of Sb and S on structure and property of vermicular graphite iron. Jiangxi Metallurgy, 1992(3):3-5. (in Chinese)
[94] ZHOU Bing. Application and preparation of combined vermiculariser for thin wall castings. Thermal Processing, 1998(6). (in Chinese)
[95] CAO Qi-zhou et al. Development of vermicularizing alloy for using cupola metal to produce heavy section vermicular iron. Modern Cast Iron, 2004(5):33-35. (in Chinese)
[96] JIANG Bing-huan et al. Investigation of rare earth vermicularizer. Cast Iron, 1994(4):28-33. (in Chinese)
[97] LI Pei et al. Process control and application of vermicular graphite iron. Foundry, 2002,51(2):57-58. (in Chinese)
[98] LUO Shu-sheng et al. Basic experiment of low-carbon vermicular iron. Modern Cast Iron, 1989(3):9-12. (in Chinese)
[99] FU Xian-qiang et al. Selection of application examples of vermicular graphite iron. National development project of the seventh 5-year program: Study on series and commercial vermicularisers, Appraisal document (5). (in Chinese)
[100] QIU Han-quan et al. Technical condition of vermicular graphite iron (draft). National development project of the seventh 5-year program: Study on series and commercial vermicularisers, Appraisal document (3). (in Chinese)
[101] YE Fang-hua et al. Metallograph of rare earth grey iron (Domestic exchange), January 1968. (in Chinese)
[102] HE Zuo-zhi et al. Thermal fatigue of grey, ductile and vermicular iron. Materials for Mechanical Engineering, 1983(2): 8-15. (in Chinese)
[103] ZHU Shi-zhen et al. Relationship between metallographic structure and physical property. Modern Cast Iron,1982(4):3-8. (in Chinese)
[104] WANG Gui-sen. Metallographic analysis of rare earth Ca vermicular graphite iron. Thermal Processing, 1983 (6). (in Chinese)
[105] HU Zhong-cheng. Experiment of thermal fatigue of rare earth vermicular graphite iron. Shangdong Machinery,1982(2). (in Chinese)
[106] HUANG Hui-song et al. Characteristics and graphite morphology of vermicular graphite iron. Science Report of Tsinghua University, December 1980. (in Chinese)
[107] DING Sen. Evaluation of thermal fatigue of grey, ductile and vermicular iron. The Fourth Annual Symposium of Shangdong Institute of Foundry, October 1983. (in Chinese)
[108] LI Chun-li et al. Study on graphite shape in vermicular graphite iron. Foundry Technology, 1981(2):8-15. (in Chinese)
[109] LI Chun-li et al. Graphite Metallography of Cast Iron - Optical and Scanning Microscopical Photos. Beijing: China Machine Press, January 1983. (in Chinese)
[110] LIU Bai-cheng and C R Loper, JR., et al. Study on formation of vermicular graphite. Ductile Iron, 1980(2). (in Chinese)
[111] LI Chun-li et al. Study on microstructure of vermicular graphite (Domestic exchange), September 1980. (in Chinese)
[112] QI Shu-yan, Institute of Locomotive & Rolling Stock Technology and Nanjing University. Observation and Study on Morphology of Vermicular Graphite iron (Domestic exchange), July 1981. (in Chinese)
[113] XIE Yuan-pu et al. Scanning microscope analysis of morphology of vermicular graphite and ductile irons. Foundry Technology, 1982(2):47-50. (in Chinese)
[114] SHU Guan-ji et al. Study on morphology and formation of various graphite in vermicular graphite iron. Journal of Nanjing University, 1983(3). (in Chinese)
[115] ZHANGZhi-shan et al. Scanning microscope study of graphite morphology in rare earth Ca-Si vermicular graphite iron. Thermal Processing, 1982(5). (in Chinese)
[116] Explanation on Metallograph Sandard of Vermicular Graphite Iron (draft), September 1983. (in Chinese)
[117] LI De-shan et al. Transmission microscope analysis of graphite morphology and microstructure in vermicular graphite iron. Foundry, 1996,45(1):36-38. (in Chinese)
[118] ZHANG Guo-zhi et al. Effect of electromagnetic field on graphite formation in cast iron. Journal of Northeastern University (Natural Science Edition), 2004(1):57-59. (in Chinese)
[119] WANG Liang-yang et al. Effect of oxygen on morphology characteristics of graphite in vermicular iron. Modern Cast Iron, 1995(1):24-27. (in Chinese)
[120] WANG Liang-yang et al. Graphite morphology of vermicular graphite iron made from Longyan pig iron. Journal of Fuzhou University (Natural Sciences Edition),1986,14(1):60-67. (in Chinese)
[121] YANG Wen-ying et al. Basic spatial morphology of vermicular graphite structure in rare earth cast iron. Journal of University of Science and Technology Beijing, 1986(2):35-44. (in Chinese)
[122] HE Zuo-zhi et al. Eutectic cells of vermicular graphite iron. Modern Cast Iron, 1982(3). (in Chinese)
[123] HUANG Hui-song et al. Eutectic cells in vermicular graphite iron. Ductile Iron, 1981(4). (in Chinese)
[124] HE Zuo-zhi et al. Eutectic cells and mechanical property of vermicular graphite iron. Materials for Mechanical Engineering, 1981,5(6):29-33. (in Chinese)
[125] FA Rui-xin et al. Investigation of solidification process of compacted graphite irons treated by different vermicularisers. Foundry, 1988,37(2):15-22. (in Chinese)
[126] LI Ke-guang et al. Solidification process of compacted/vermicular graphite cast iron treated with various graphitizing alloys. Journal of Shenyang University of Technology,1986(1):7-17. (in Chinese)
[127] ZHU Zhen-hua et al. Study on eutectic cells of vermicular graphite iron. Modern Cast Iron, 1991(4):4-8. (in Chinese)
[128] LU Wen-hua et al. Effects of wall thickness and graphitisation on structure and property of vermicular graphite iron. Foundry Technology, 1984(3):35-38. (in Chinese)
[129] TAN Chong-yu et al. Experimental study on vermicular graphite iron treated with Mg-Ti alloy- Preparation of high pearlite cylinder liner. Science and Technology Report of Xi'an Jiaotong University, March 1981. (in Chinese)
[130] WANG Yi-de et al. Rare earth boron vermicular graphite iron. Ductile Iron,1981(2). (in Chinese); Shangdong Machinery, 1981 (1). (in Chinese)
[131] MENG Tai et al. Rear earth pearlitic vermicular graphite iron steel ball grinding plate. Shangdong Machinery, 1982(5) (in Chinese); Modern Cast Iron, 1982(5). (in ; Chinese)
[132] WANG Jia-xin et al. Study of fundamental structure of rare earth vermicular graphite iron. Ductile Iron, 1982(1):17-23. (in Chinese)
[133] Tsinghua University. Scanning microscope metallography of cast iron. Science report of Tsinghua University, September 1978. (in Chinese)
[134] Beijing Erqi Locomotive & Rolling Stock Plant. Metallography of Vermicular Graphite Cast Iron, December 1979. (in Chinese)
[135] Beijing Erqi Locomotive & Rolling Stock plant . Metallography of Vermicular Graphite Cast Iron, June 1979. (in Chinese)
[136] YE Fang-hua et al. Metallography of Rare Earth Vermicular Graphite Cast Iron (Domestic exchange), September 1981. (in Chinese)
[137] HE Zuo-zhi et al. Metallograph of Vermicular Graphite Cast Iron, September 1982. (in Chinese)
[138] Shanghai, Nanjing and Hangzhou Federation of Foundry. Metallograph standard of vermicular graphite cast iron (draft). Modern Cast Iron, 1983(1):3-8. (in Chinese)
[139] No. 12 Institute of China Shipbuilding Industry Corporation. Metallograph Standard of Vermicular Graphite Cast Iron (GB1030-83). Thermal Processing, 1984(3). (in Chinese)
[140] ZHU Zhen-hua et al. Discussion on Primary Crystallisation of Vermicular Graphite Cast Iron. Proceedings of 1984 National Symposium of Primary Crystallisation of Vermicular Graphite Cast Iron, 1984. (in Chinese)
[141] DENG Xi-jun et al. Mechanism and formation of vermicular graphite. Journal of Harbin University of Science and Technology (Science Research Report), 1984(28) (in Chinese); Proceedings of 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[142] ZHU Pei-yue et al. Effect of Inclined Twin in Graphite Growth. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[143] LIU Bai-cheng et al. Vermicular graphite during solidification process. Ductile Iron, 1983(3). (in Chinese)
[144] CHEN Jia-yu et al. Study on Liquid Channel during Solidification of Vermicular Graphite Iron. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[145] NIU Yin-yi et al. Chunky Graphite during Slow Cooling of Vermicular Graphite Iron. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984:20. (in Chinese)
[146] XIE Pu-yuan et al. Discussion of formation mechanism of vermicular graphite iron. Shandong Machinery, 1980(4). (in Chinese)
[147] SUN Guo-xiong and C R Loper, Jr. Graphite Morphology and Formation Characteristics of Compacted Graphite Iron. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[148] PAN Zhen-hua. Study on Formation Mechanism of Vermicular Graphite. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[149] GAN Yu and C R Loper, Jr. Observation of Graphite Formation Process of Spheroidal and Compacted Graphite. 1984 National

Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[150] FAN Zhi-kang et al. Study on Orientation Relationship in Two Dimensional Intercept and Three Dimensional Space of Vermicular Graphite. 1984 National Symposium of Primary Solidification of Vermicular Graphite Iron, 1984. (in Chinese)
[151] YAO Xin et al. Crystallite morphology of vermicular graphite. Ductile Iron, 1985(1):66-68. (in Chinese)
[152] ZHOU Bing et al. Study on the primary crystalisation of vermicular graphite iron under different cooling rates. Ductile Iron, 1978 (2). (in Chinese)
[153] ZHOU Bing et al. Study of graphite formation mechanism of vermicular graphite iron. Thermal Processing, 1998(6). (in Chinese)
[154] LI Xiu-zhen et al. Twisting and vermicularisation of graphite during growth process in cast iron. Modern Cast Iron, 1997(3): 21-24. (in Chinese)
[155] TAO Rui-jin. Mechanical properties of as cast and heat treated rare earth V-Ti vermicular graphite iron. The First Symposium of Chinese Institute of Rare Earth, September 1980. (in Chinese)
[156] XU Han-fan et al. Study on normalization process of vermicular graphite iron. Modern Cast Iron,1982(2):23-26. (in Chinese)
[157] YOU Zu-yin. The normalization of compacted-vermicular graphite iron. Journal of Suzhou University (Technology edition), 1987(3): 57-61. (in Chinese)
[158] HU Zhong-cheng et al. Discussion on Heat Treatment Process of Vermicular Graphite Iron (Domestic exchange) January 1982. (in Chinese)
[159] HU Zhong-cheng et al. Study on structure and property of austempered rare earth vermicular graphite iron (Domestic exchange), 1984(7). (in Chinese)
[160] LIU Guan-jun et al. Effect of austempering on structure and property of vermicular graphite iron. Foundry, 1999 (11):41-43. (in Chinese)
[161] YANG Fang et al. Investigation on lath-martensite strengthening and the wear resistance of compacted/vermicular graphite iron. Journal of Suzhou University (Science and Technology edition), 1990, 10(1) 63-67. (in Chinese)
[162] ZHAO Hao-feng et al. Effect of rare earth on structure and property of waste heat hardened wear resistant low alloy vermicular graphite iron. Chinese Rare Earths, 1999(1):38-40. (in Chinese)
[163] Jiangxi Institute of Machinery et al. Ball grinding plate of tungsten heavy rare earth vermicular graphite iron. Foundry, 1980(5):54-55. (in Chinese)
[164] SHANG Ping et al. Study on the boronising-chromising vermicular graphite iron. Journal of University of Science and Technology, 1994(1):32-35. (in Chinese)
[165] FENG Zu-wang. Camshaft made from Cu-Mo-Sn vermicular graphite iron. Foundry Engineering, 1982(3). (in Chinese)
[166] ZHANG Zhi-shan et al. Experimental study on strengthening of vermicular graphite iron. Thermal Processing, 1985(1). (in Chinese)
[167] ZHAO Hong et al. Recent researches on austempered cast iron. Foundry, 2001, 50(5):1-6. (in Chinese)
[168] CHAI Yao-sheng et al. Discuss about the structure design of vermicular graphite cast iron and the choice of austempering temperature range. Journal of Taiyuan Heavy Machinery Institute, 1994(2):160-163. (in Chinese)
[169] JI Qian-mao et al. Microstructure and Properties of Rare Earth Austenite-Bainite Vermicular Graphite Iron. The Six Annual Foundry Conference of Shangdong Institute of Mechanical Engineering, October 1989
[170] ZHANG Zhi-shan et al. Study on as-cast austenite-bainite vermicular graphite iron. Thermal Processing, 1987(1): 13-19. (in Chinese)
[171] SHENG Da et al. Microstructure and mechanical properties of austenite-bainite vermicular graphite iron at high temperature. Journal of Iron and Steel Research, 1997, 9(1):41-45. (in Chinese)
[172] SHENG Da et al. Investigation on austempereed vermicular graphite iron and properties at high temperature. Modern Cast Iron, 1999(3): 23-27. (in Chinese)
[173] YAN Bing-xiang et al. Dependence of properties of rare earth austenite-bainite compacted graphite cast iron on temperature. Chinese Rare Earths, 1999(5):38-42. (in Chinese)
[174] YE Ding-min et al. Metallurgical Characteristics of V-Ti Vermicular Graphite Iron. 1982 Sichuan Province Annual Foundry Conference. (in Chinese)
[175] JING Cheng-hui. Summary on machining of rare earth Ca high strength grey iron (Appraisal document), June 1980. (in Chinese)
[176] AN Chao-wen et al. C/V graphite cast iron hydraulic valves produced from vermicular graphite iron. Modern Cast Iron, 1990(3):33-34. (in Chinese)
[177] ZHAN Jian-zeng. Machining performances of compacted graphite iron. Journal of Jiangsu University (Natural Science Edition),1988,9 (3) :65-74. (in Chinese)
[178] TIAN Yong-sheng et al. Effect of SG modification agents on machining property of alloyed vermicular graphite iron. Foundry, 1997, 46(8):46-47. (in Chinese)
[179] PAN Jun et al. Study review and prospect of PCBN cutting cast irons. Tool Engineering, 2004, 38(10):3-6. (in Chinese)
[180] ZHANG Xiao-hong et al. Temperature and thermal stress field of vermicular graphite iron in welding. Development and Application of Materials, 1997,12(4). (in Chinese)
[181] ZHOU Zhen-feng et al. The investigation of homogeneous electrode for arc cold welding weld of compacted graphite cast iron. Journal of Jilin University of Technology (Natural Science Edition), 1988(2): 111-121. (in Chinese)
[182] LU Xin-hong, Chinese patent: 02139427.X
[183] ZHOU Zhen-feng. Welding Metallurgy and Process of Cast Iron. Beijing: China Machiner Press. (in Chinese)
[184] ZOU Ming-hui et al. Chrome plating of vermicular graphite iron castings. Electroplating & Pollution Control,1995(4):29. (in Chinese)
[185] QU Zhan-min. Discussion on decorative chrome plating of vermicular graphite iron castings. Materials Protection, 2003(1):58. (in Chinese)
[186] SHI Rui-he et al. Research on the damping property of cast iron. Foundry, 1987, 36(11):12-16. (in Chinese)
[187] FANG Shi-hong. In front furnace fast inspection and control for vermicular graphite iron. Ductile Iron 1985(2):58-59. (in Chinese)
[188] PEI Yan-kui. Metallography inspection of vermicular graphite iron in front furnace. Automobile Science and Technology, 1998 (1):48-49. (in Chinese)
[189] YANG Yun-feng et al. Rapid determination of modularity and vermicularity of cast irons by measuring the oxygen potential. Modern Cast Iron, 1988(3):36-40. (in Chinese)
[190] YANG Yun-feng et al. Metallurgical factors of cast iron modification and their monitoring. Journal of Tsinghua University (Natural Science Edition) 1988, 28(2):1-11. (in Chinese)
[191] TAO Guo-gang et al. Study on in front furnace fast inspection technique for vermicular graphite iron quality. Research Studies on Foundry Equipment, 2000(1):39. (in Chinese)
[192] ZHANG Jun et al. Relationship between analysis errors of rare earth contents of vermicular graphite iron and sample preparation analysis. Modern Cast Iron, 1994(3):58-62. (in Chinese)
[193] CHEN Li et al. Fast and full analysis of chemical composition of vermicular graphite iron brake plate. Locomotive & Rolling Stock Technology, 2003(5). (in Chinese)
[194] CHEN Ya-li et al. Determination of trace amounts of calcium in vermicular cast. Journal of Fuzhou University (Natural Science Edition) 1988,16(3):199-203. (in Chinese)
[195] BIAN Long-sheng et al. Discussion of vermicular graphite morphology distribution and testing method. Shanxi Machinery, 1996(4):19-21. (in Chinese)
[196] http://www.qctester.com/BieJingWanTaiJiShuKaiFaGongShi.htm
[197] CHEN Xin et al. Research on non destructive testing technique of compactizing quality in compacted graphite cast iron. Journal of Wuhan Automotive Polytechnic University, 1999 (2):52-55. (in Chinese)
[198] WANG Qu-gong et al. Acoustical testing of vermicular graphite iron manifold quality. Non-Destructive Testing, 1999, 22(1):30-31. (in Chinese)
[199] YANG Jun-qiang et al. Acoustical testing of vermicular graphite iron flying wheels, 1998(2). (in Chinese)
[200] ZHANG Song et al. Inspecting Technology for Casting Quality of Cylinder-head in Diesel Engine. Internal Combustion Engines, 2002 (2):33-34. (in Chinese)
[201] ZHANG Song et al. Using ultrasonic velocity method to check and measure the vermicular graphite quality in the diesel engine cylinder head made of vermicular graphite cast iron. Vehicle Engine, 2002(3):41-42. (in Chinese)
[202] HU Yi-hua et al. Establishment and application of the data management and analysis system for compacted graphite iron castings quality. Research Studies on Foundry Equipment, 2002(2):29-30. (in Chinese)
[203] Chinese Institute of Automotive. Explanation of significant progress of automotive technology during ninth five year project. Automotive Engineering, 2001, 23(3):75-76. (in Chinese)
[204] WAN Ren-fang et al. Study and volume production of vermicular graphite iron exhaust manifolds. Automobile Science and Technology, 1994 (6):3-9. (in Chinese)
[205] DUAN Han-qiao et al. Production study on new generation of VG cast iron exhaust manifolds. Automotive Science and Technology, 2002 (3):13-16. (in Chinese)
[206] DUAN Han-qiao et al. The reason of low elongation of medium Si-Mo vermicular graphite iron exhaust manifolds from processing. Thermal Processing, 2002(2). (in Chinese)
[207] YUAN Fu-an et al. Application of factor design method to studying on mid-Si-Mo VG cast iron for exhaust tube casting. Foundry, 2002,51(3):52-55. (in Chinese)
[208] LI Xia-zhou et al. Study on the production process of vermicular graphite iron exhaust manifolds. Moulding Materials, 2004. (in Chinese)

[209] WU Wei-ming et al. Study on the treatment method of vermicular graphite iron exhaust manifolds. Foundry Engineering (Molding Materials), 2000(4). (in Chinese)
[210] ZHAO Yu et al. The manufacture of ultra thin wall exhaust by vermicular graphite cast iron. Journal of Jilin Institute of Technology, 1999, 20(1):45-49. (in Chinese)
[211] JI Ren-qiang et al. Experiment and study of vermicular graphite iron. Dalian Machinery, 1983(1). (in Chinese)
[212] ZHANG Shu-shan et al. Production practice of vermicular graphite iron exhaust manifolds. Foundry Engineering (Moulding Materials), 2003(3):36-37. (in Chinese)
[213] ZOU Shi-kui et al. Production of medium velocity diesel engine cylinder heads using vermicular graphite iron. Foundry, 1992, 41(5):40-42. (in Chinese)
[214] YAN Yuan-yuan et al. Production of vermicular graphite iron cylinder heads. Mechanics (Thermal Processing), 1982(6):26-29. (in Chinese)
[215] FAN Xu-chu et al. Production of high power vermicular graphite iron diesel engine cylinder heads using cupola iron. Modern Cast Iron, 1983(2). (in Chinese)
[216] ZHOU Gen. An approach to foundry method of vermicular iron cylinder head for vehicle diesel engine. Modern Cast Iron, 2003 (5):39-43. (in Chinese)
[217] ZHANG Wei-de et al. Volume production of vermicular graphite iron diesel engine cylinder heads using cupola iron. Foundry, 1987, 36(12):26-29. (in Chinese)
[218] ZHOU Ying-nan et al. Study on rare earth vermicular graphite iron diesel engine cylinder heads. Modern Cast Iron, 1988(2):34-37. (in Chinese)
[219] TANG Li et al. Application of rare earth alloy in the production of vermicular graphite iron cylinder heads. Modern Cast Iron, 1998 (3):44-47. (in Chinese)
[220] FAN Li et al. Development of high strength wear resistant materials for thin wall cylinder blocks. Vehicle Engines, 1999(4):1-4. (in Chinese)
[221] CHEN Wei-ming et al. Performance and application of compacted graphite iron produced by sintercast process. Automobile Technology and Materials, 1999(11):22-24. (in Chinese)
[222] Shanghai University et al. Study and application of low alloy vermicular graphite iron in cylinder blocks of rock drill of internal combustion engine. Modern Cast Iron, 1983(4):13-17. (in Chinese)
[223] GU Guang-xi et al. Study on the C/V pearlitic cast iron for compressor cylinder blocks. Modern Cast Iron, 1988(4):16-18. (in Chinese)
[224] LUO Jing-hua et al. Study of single cast vermicular graphite iron piston rings. Modern Cast Iron, 1988(1):34-36. (in Chinese)
[225] WANG Yu-shun et al. Application of vermicular graphite iron piston rings in maintenance of E207J diesel engine. Diesel Locomotive, 1996(6):41-46. (in Chinese)
[226] HUANG Peng-xiang et al. Vermicular graphite iron piston rings in medium to large diesel engine. Modern Cast Iron, 1984(3):29-31. (in Chinese)
[227] YANG Jia-rong et al. Study on vermicular graphite iron piston rings. Modern Cast Iron, 1986(3):3-5. (in Chinese)
[228] WANG Qi-hong. Exploration of worm graphite cast iron piston ring. China Foundry Equipment and Technology, 1997(5):7-9. (in Chinese)
[229] YUE Xi-chen et al. RE-Boron C/V cast iron cylinder lining. Modern Cast Iron, 1991(2):47-49. (in Chinese)
[230] LI Quan-an et al. Wear characteristics of compacted graphite iron in asbestos-based friction materials/compacted graphite iron friction pair. Journal of Luoyang Institute of Technology, 1996(3):1-4. (in Chinese)
[231] ZHANG Yong-zhen et al. Application of compacted graphite cast iron to railroad vehicles braking system. Foundry Technology, 2002(1):45-47. (in Chinese)
[232] CHEN Sheng-li et al. Bench test and research on brake discs of vermicular graphite cast iron. Railway Vehicle, 2004(4):11-14. (in Chinese)
[233] SUN Ge-sen et al. Application study of phosphorous vermicular graphite iron brake shoes. Railway Vehicle, 1994(11):16-19. (in Chinese)
[234] ZHANG Yong-zhen et al. Research on tribological properties of railroad brake shoes made of compacted graphite cast iron. Tribology, 1995(3):236-242. (in Chinese)
[235] ZHAO En-le et al. Structure and property of boron bearing vermicular graphite iron brake shoes. Journal of Luoyang Institute of Technology, 1996(2) ):12-16. (in Chinese)
[236] SHEN Bai-ling et al. Tribology of vanadium bearing vermicular graphite iron under dry friction. Journal of Iron and Steel Research, 1997(3):52-55. (in Chinese)
[237] KOU Hong-chao et al. Wear and friction property of Cr bearing vermicular graphite iron. Thermal Processing, 1997(6). (in Chinese)
[238] SHANGGUAN Bao et al. Effects of Mn and CE on structure and wear property of vermicular graphite iron. Thermal Processing, 2004(8). (in Chinese)
[239] YIN Yan-dong et al. The simulation and optimisation of casting method of passenger train coach braking discs. Foundry, 2000(4):33-36, 44. (in Chinese)
[240] ZHAO Zheng-xiong et al. High velocity passenger train vermicular graphite iron braking plates (Φ 640). Meiguang Science and Technology, 2001(12-11). (in Chinese)
[241] ZHANG Yong-zheng et al. Material transfer in contact surface during dry friction of phosphorous compacted graphite iron coupled with 40Cr quenched steel. Weapons Materials Science and Engineering, 1995(4) :15-18. (in Chinese)
[242] ZHANG Yong-zheng et al. Wear characteristics of 40Cr quenched steel in phosphorous compacted graphite iron/40Cr steel friction pair. Journal of Luoyang Institute of Technology, 1995(3):1-5. (in Chinese)
[243] CHEN Yue et al. Study on the temperature field of friction surface during dry friction of phosphorous bearing vermicular graphite iron. Water Conservancy & Electric Power Machinery, 1997,19(3): 33-37. (in Chinese)
[244] ZHENG Zuo-yong et al. Investigation of fractal characteristics and tribological properties of dry sliding surface of phosphorous compacted cast irons. Journal of Luoyang Institute of Technology, 2000(2) :12-15. (in Chinese)
[245] ZHANG Yong-zhen et al. Investigation of topographical characteristics and tribological behavior of compacted graphite iron in sliding against 40Cr steel under different dry sliding conditions. Tribology, 2001(1):38-42. (in Chinese)
[246] KOU Chao-hong et al. Study on the worn surface morphology of vermicular graphite iron under dry tribology. Tribology, 2000(2):31-35. (in Chinese)
[247] ZHANG Yong-zhen et al. 3-D Topographical characteristics of dry sliding surface of compacted graphite irons coupled with chromium steel disk. Tribology, 2000(6):8-12. (in Chinese)
[248] ZHANG Yong-zhen. Influence of counterpart volume ratio on tribological characteristics in dry sliding couple of cast irons against steel. Journal of Luoyang Institute of Technology, 2000(3):3-6. (in Chinese)
[249] TANG Xiao-hua et al. Low cycle fatigue crack growth rate of compacted graphite cast iron. Journal of Tsinghua University (Natural Science Edition), 2004, 44(11):20 -23. (in Chinese)
[250] LI Yun-hui et al. Effect of graphite morphology and alloying elements on thermal fatigue resistance of cast iron. Modern Cast Iron, 2001(3):13-15. (in Chinese)
[251] ZHU Zheng-yu et al. Thermal fatigue properties of vermicular cast irons with different matrix structures. Modern Cast Iron, 2005 (6) :11-14. (in Chinese)
[252] WEN Guang-min et al. Production and application of vermicular graphite ingot moulds. Mining and Processing Equipment, 1999(10): 59-60. (in Chinese)
[253] HAN Rui-ru. Manufacture of vermicular graphite ingot moulds. Science & Technology of Baotou Steel (Group) Corporation, 1989(2):61. (in Chinese)
[254] JIN Chao-you. Effects of composition, microstructure and mechanical property on the service life of small vermicular graphite iron ingot moulds. Ductile Iron, 1984(1):37-41. (in Chinese)
[255] QIU Han-quan et al. Manufacture of vermicular graphite ingot moulds using rare earth Zn vermiculariser. Shangdong Machinery, 1984 (2). (in Chinese)
[256] BAI Zhi-chun et al. Summary of manufacture of 280 kg vermicular graphite ingot moulds. Foundry Technology, 1982(4):32,47. (in Chinese)
[257] SHENG Da et al. Experiment on the manufacture of 4.5 tons ingot moulds of RE-Mg treated vermicular graphite cast iron. Iron and Steel, 1982(4):25-31. (in Chinese)
[258] SHANG Qing-shan et al. Study on C/V cast iron ingot mold. Modern Cast Iron, 1990(3):42-43. (in Chinese)
[259] CHEN Jun-de et al. The application of rare earth cast ingot moulds. Journal of Guizhou University of Technology (Natural Science Edition), 1998,27(5):41-44. (in Chinese)
[260] CHEN Jing-ju et al. The microstructure and properties of vanadium-titanium c/v iron ingot mould. Modern Cast Iron, 1988(3):13-15. (in Chinese)
[261] ZHOU Bin et al. Manufacture of vermicular graphite iron ingot moulds using Mianning pig iron. Thermal Processing, February 2000. (in Chinese)
[262] LI Chang-sheng et al. Application of vermicular graphite iron in aluminium ingot moulds. 1984 Shangdong Conference on Expanding Application of Rare Earth. Casting Production, 1985(1). (in Chinese)
[263] Lanzhou Foundry. Summary on production of rare earth high strength grey iron. Conference on thermal process of national water pump industry, 1982. (in Chinese)
[264] Xinhua news:Shangdian Aluminium developed compacted graphite iron aluminium ingot moulds, 2002-12-4 16:22:53, http://shangdianlvye.com/meiti/zxxwshow.asp?id -161
[265] HE Chun. Application of vermicular graphite iron in aluminium

ingot moulds. Foundry Engineering (Molding Materials), 2002,1: 31-32. (in Chinese)
[266] ZHAO Ru-jin. Vermicular graphite iron six inches steel ingot mould and 400 coupling box in steel rolling mill. Ductile Iron,1983(2): 28-29. (in Chinese)
[267] YAO San-jiu et al. Study on quenching car compacted graphite iron liner. Hebei Metallurgy, 1994(2):50-53. (in Chinese)
[268] YAO San-jiu et al. Quenching car liner made from compacted graphite iron. Modern Cast Iron, 1994(4):82-83. (in Chinese)
[269] GU Ling et al. Application of compacted graphite cast iron in designing the protecting iron casting in coke oven. Shandong Metallurgy, 2002(1):44-46. (in Chinese)
[270] LI Fang-tian et al. Manufacturing of coke oven parts by vermicular graphite cast iron. Foundry Technology, 1998(1):6-7. (in Chinese)
[271] WANG Qing-feng et al. Development of rare-earth vermicular graphite cast iron oven armours for 6m coke oven. Fuel & Chemical Processes, 1997(2):16-19. (in Chinese)
[272] XU Jia-wen. Quality control of vermicularisation of vermicular graphite grade 400. Foundry Technology, 2003(4):36-37. (in Chinese)
[273] ZHANG Kui-chen. Production of Vermicular Graphite Iron Glass Moulds and Application in Small Mechanized Glass Bottle Machine. The fourth Shandong foundry annual conference, 1983. (in Chinese)
[274] YU Jin-xin et al. Application of vermicular graphite iron in glass moulds. Shandong conference on rare earth application; Gongjiao Technology Exchange, 1984(3-4):8-12. (in Chinese)
[275] Wang Hu et al. Application of alloyed vermicular graphite iron in glass moulds. Ductile Iron, 1985(1):37-38. (in Chinese)
[276] ZOU Si-cheng et al. Experimental study on low alloy vermicular graphite iron in glass moulds. Modern Cast Iron, 1989(1) :8-11. (in Chinese)
[277] ZHANG Jin-shan et al. Microstructure and properties of low alloy compacted graphite cast iron used in glass moulds. Journal of Taiyuan University of Technology, 2000(2):106-107. (in Chinese)
[278] XU Jin-shan et al. Rare earths, potassium and sodium micro-alloying ferrite vermicular graphite cast iron for making glass mould. Journal of the Chinese Rare Earth Society, 2003(03):68-71. (in Chinese)
[279] ZHANG Jin-shan et al. Study on micro-alloying compacted graphite cast iron used in glass mould. Research Studies on Foundry Equipment, 2003(3):9-11. (in Chinese)
[280] WANG HU et al. Application of rare earth vermicular graphite iron glass moulds in China. Foundry, 1990, 39(12):4-7. (in Chinese)
[281] http://www.mould-bottle.com
[282] WANG Hu et al. Glass moulds made from rare earth vermicular graphite iron, Chinese patent: 85107725
[283] WANG Hun et al. Changing graphite morphology of vermicular graphite iron by sulphur bearing material, Chinese patent: 85102362
[284] LI Lian-zhi et al. Glass mould and production process, Chinese patent: 85108041
[285] Lu Lian-yi et al. Vermicular graphite cast iron bottle pliers. Ductile Iron, 1984(1):50. (in Chinese)
[286] LI Da-ming. Study on grain refining of heavy section hydraulic castings. Guangdong Machinery, 1981(2):27-32. (in Chinese)
[287] ZHOU Ying-nan. Vermicular graphite iron hydraulic castings. Ductile Iron, 1985(4):46-47. (in Chinese)
[288] Chongqing Excavator Plant et al. Experiment and production of rare earth vermicular graphite iron. Sichuan Annual Foundry Conference, 1982. (in Chinese)
[289] YANG You-kun et al. Application of V-Ti vermicular graphite iron in hydraulic valves. Journal of Qinghai University, 2001(6):45-46. (in Chinese)
[290] XU Gui-ren et al. Production of Vermicular Graphite Iron Casting Using Cupola Iron. National conference on study, production and application of vermicular graphite iron, 1991. (in Chinese)
[291] HUANG Peng-xiang et al. Production of vermicular graphite iron and application in heavy machinery. (Domestic exchange), July 1983. (in Chinese)
[292] RAO Wen-xiong. Application of vermicular graphite iron in planer. Mechanics (Thermal Processing), 1983(2):28-30
[293] ZHANG Guo-chen. Application of vermicular graphite iron in double housing planer. Mechanics (Thermal Processing), 1983 (2):23-28. (in Chinese)
[294] LI Hua-pei. Production of vermicular graphite iron using local pig iron. Materials For Mechanical Engineering, 1979(1):41-50. (in Chinese)
[295] QIU Hun-quan et al. Application of vermicular graphite iron in material test machine and machine tool castings. Materials For Mechanical Engineering, 1983(2):20-22. (in Chinese)
[296] WANG Hu et al. Summary on the study of railway vehicle gear box made from vermicular graphite iron. Foundry Technology, 1984(2) :39-42. (in Chinese)
[297] PAN Zhen-hua et al. Summary on railway vehicle gear box made from vermicular graphite iron. National symposium of rare earth application in cast iron, September 1981. (in Chinese)
[298] Chongqing University et al. Study and production on vermicular graphite iron VTR251 turbo gas-in housing. Sichuan Annual Foundry Conference, 1982. (in Chinese)
[299] XING Jun-de et al. Study and production on vermicular graphite iron VTR251 turbo gas-in housing. No.12 Institute of China Shipbuilding Industry Corporation, Science report: K8204.1982.7
[300] WANG Tie-cheng. Casting of vermicular graphite iron grooved drum. Foundry, 1986,35(11):29-31. (in Chinese)
[301] http://www.gxu.edu.cn/gxu/college_institution/college/xueyuan/jxxy/xyjj/
[302] CHEN Ru-xia et al. Casting production of squeeze press roll with phosphor-boron vermicular graphite cast Iron. Research Studies on Foundry Equipment, 2003(4):38-39. (in Chinese)
[303] GUO Er-jun. Experimental study on vermicular graphite iron die made by ceramic precision casting. Journal of Harbin University of Science and Technology, 1998(1):27-30. (in Chinese)
[304] SUN Yu. Experimental study of vermicular graphite iron die. Mechanical Engineer, 2003(6):42-43. (in Chinese)
[305] HUA Jia. Study on vermicular graphite iron pipes. Ductile Iron, 1987(3):52. (in Chinese)
[306] ZHAO Shu-ye et al. Application of vermicular cast iron pipes in the sub-high pressure town gas. Gas & Heat, 1989(2):28-32. (in Chinese)
[307] CHEN Ling et al. Application of vermicular graphite iron in production of ceramic machinery. Jiangsu Ceramics, 1998(3):15-16. (in Chinese)
[308] REN Ju-liang. Rolls mould made from vermicular graphite iron. China Foundry Machinery & Technology, 1996(4):33-34. (in Chinese)
[309] QIU Yao-ping. Casting of decorative Glass Lamp moulds. Modern Cast Iron, 2000(1):49-50. (in Chinese)
[310] Qingdao Tianhua Yihe Castings, http://www.wjw.cn/CompanyShow/Company/CompanyDocoment.asp?ID=29614
[311] Yuchai Machinery Spare Parts Manufacturer, http://gxylycjq.cn.china.cn/op/ProductDetail/pdtid/1015896641/categoryType/product/index.htm
[312] Fuzhou Weishi Machinery Ltd., http://www.fzwealth.com/yst.htm
[313] Technogical and Scientific Achievements of Heilongjiang Province, 2001-0410 http://www.hljkjt.gov.cn/cc.asp?Page=401
[314] Yao Hui et al. Current status and development of casting patterns (2), http://www.ceblog.cn/user1/18/archives/2006/3135.htm
[315] Foundry Division of Shanghai University of Science and Technology. Rare earth Mg low alloy vermicular graphite iron. (internal document) 81-118. (in Chinese)
[316] WANG Shu-fang. Study on property of B-Cu vermicular graphite iron. Journal of Changchun University of Technology (Natural Science Edition),1992(Z1):48-54. (in Chinese)
[317] ZHANG Zhong-qiu et al. Property of Rare earth Mg-Ti vermicular graphite iron. Foundry, 1986,35(9):10-17. (in Chinese)
[318] Beijing Institute of Electro-Machinery et al. Application of V-Ti vermicular graphite iron in glass moulds (Domestic exchange), November 1983. (in Chinese)
[319] YE Ding-tao et al. Application of V-Ti vermicular graphite iron in special automotive. Ductile Iron, 1987(1):50-51. (in Chinese)
[320] CHEN Shi. Production and control of V-Ti vermicular graphite iron. Modern Cast Iron, 1990(2):33-34. (in Chinese)
[321] WANG Hu et al. Summary of experiments on V-Ti-Cu-Cr vermicular graphite iron glass moulds. Foundry, 1983,32(4):35-40. (in Chinese)
[322] LUO Shi-ping et al. Application study of rare earth V-Ti-Al-Si cast iron. Foundry, 1983, 32(4):29-34. (in Chinese)
[323] HE Ting-chu. Metallographic structure and application of rare earth V-Ti-Al-Si cast iron. Sichuan Machinery, 1983(11). (in Chinese)
[324] LI Xiu-zheng et al. Study and application of medium silicon heat resistant vermicular graphite iron and its application. Foundry, 1997,46(2):20-22. (in Chinese)
[325] JIANG Cheng-ling. Application of Si-Mo heat resistant vermicular graphite iron in centrifugal casting moulds. Thermal Processing, 2002(1). (in Chinese)
[326] WU Ming-hai et al. Effect of molybdenum on the mechanical properties in high temperature of the compacted graphite cast iron with medium Si content. Modern Cast Iron, 1991(2):39-41. (in Chinese)
[327] Murthy V S and XIANG Ming. Copper molybdenum alloy vermicular graphite iron. Foundry, 1989,38(2):48. (in Chinese)
[328] LI Yun-hui et al. Study on new vermicular graphite iron suitable for thin wall castings. Chinese Foundry Equipment and Technology, 1999(3):14-16. (in Chinese)
[329] YANG Tong et al. Investigation on the thermo-physical properties of Al-Si-Cr-Mo alloyed compacted graphite cast iron. Journal of Xi'an Institute of Technology, 1994(1):14-23
[330] ZHANG Qing-lai. Al-B low Si vermicular graphite iron. Foundry, 1996, 45(7):25-28. (in Chinese)
[331] YANG Jia-rong et al. Effect of Niobium and Niobium bearing compounds on wear resistance of vermicular graphite iron. Modern Cast Iron, 1988(1):9-12. (in Chinese)
[332] DING Sen et al. Selected applications of vermicular graphite cast iron. Foundry, 1981, 30(5):28-34. (in Chinese)