Casting Process of Improving Cutting Machining Properties of Vermicular Graphite Cast Iron

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Keywords: Vermicular Graphite Cast Iron, Origin and Development, Casting Process, Cutting Machining, Tool-break and Problem Treatment.

Abstract: Based on casting process of vermicular graphite cast iron, we can improve cutting properties, stability and machining efficiency for decrease of casting scrap and application in other fields. Combined with development and casting process of vermicular graphite cast iron, the work analyzed problems such as tool-break in cutting machining. After that, the work proposed suggestions to improve machining efficiency and casting process in vermicularizing, inoculating and heat treating for promotion of cutting properties and production efficiency.

1 INTRODUCTION

With good thermal conductivity, toughness and anti-fatigue, vermicular graphite cast iron has been widely used in industrial society. Casting process of vermicular graphite cast iron has made great progress in application and research for half a century. However, unstable factors in production caused high scrap as well as poor production deficiency and cutting machining properties, thus affecting development of casting industry. Optimization of casting process, as well as improvement of vermicular graphite rate and inoculant effect, is the key of developing cutting machining of vermicular graphite cast iron.

2 DEVELOPMENT AND CASTING PROCESS OF VERMICULAR GRAPHITE CAST IRON

2.1 Origin of Vermicular Graphite Cast Iron

In 1947, H.Morrogh found that an element—cerium could be added to improve iron properties. Spherical graphite also makes significance in casting process. In 1948, thick lamellar graphite was considered as a bad spheroidization product by adding magnesium in casting. Research showed that the smelting technology had an active significance in developing strength and fatigue resistance of cast iron. After that, the concept of vermicular graphite cast iron was proposed. In 1960, vermicular graphite cast iron was developed in USA, Japan, Germany, etc. J.W.Estcs firstly applied vermicular iron to casting for systematization of vermicular graphite cast iron theory in 1965. Vermicular graphite cast iron has advantages including good strength, thermal conductivity, heat resistance and anti-fatigue. After that, vermicular graphite cast iron was greatly developed.

2.2 Development of Vermicular Graphite Cast Iron

Vermicular graphite cast iron was in production in 1948. With a production of 50,000 tons, its application was not mature. After that, vermicular graphite cast iron was developed. The productions were 53.5, 500 and 915 tons in 1960, 1970 and 2000, respectively. Vermicular graphite cast iron has advantages of high tensile strength, anti-friction, elongation and impact toughness. With properties between gray and ductile iron, it was used for part casting. Production technology of vermicular graphite cast iron has reached a high level by experiments and research in many countries. At present, vermicular graphite cast iron, with great potential, is widely used in car engine, cylinder cover of internal combustion engine in train, etc.

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DOI: 10.5220/0006023102360239
In *Proceedings of the Information Science and Management Engineering III (ISME 2015)*, pages 236-239
ISBN: 978-989-758-163-2

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2.3 Development of Vermicular Graphite Cast Iron in China

As one of leading countries of vermicular graphite cast iron research, China successfully developed this technology for production in 1950. The production of vermicular graphite cast iron in China is less than USA and Japan at present. Vermicular graphite cast iron technology was applied to improve life of ductile iron ingot mold in Baotou Steel Factory in 1960s. In 1966, Shandong Machinery Design and Research Institute published the thesis about vermicular graphite cast iron technology. Then research on vermicular graphite cast iron went into an active period. Using magnesium and rare earth as the vermiculizer, the production process is unstable. However, research of vermicular graphite cast iron was selected as one of 7th and 8th five-year communication projects by government. The application was not developed until 1990s. There is certain deficiency in research and development of application. E.g., research on tensile strength in China was lower than advanced level in the world. The tensile strength of vermicular graphite cast iron is about 450MPa. In common application, the key of research is processing technology rather than tensile strength.

2.4 Casting Process of Vermicular Graphite Cast Iron

Casting process of vermicular graphite cast iron consisted of material selection, vermicularizing and inoculating. Material selection was the basis of vermicular graphite cast iron. Firstly, cast iron with less S, P and Si was selected for stability of casting. Secondly, gray cast iron had a high sulfur content and bad stability. Therefore, vermicular and ductile iron, rather than gray cast iron, was selected as scrap returns, thus improving casting and cutting quality. Thirdly, steel scrap with low carbon content was selected for machining. Fourthly, in special vermicular graphite cast iron, materials with better performance were used to ensure quality of vermicular iron. E.g., carbon content can affect casting performance instead of strength. Therefore, this property should be considered to change carbon content. Pig iron content was more than 50%, and scrap return less than 40%. Other elements were determined as required. Experiments were conducted to ensure scientific addition of elements and production quality of vermicular iron. Vermicularizing was the key of vermicular graphite cast iron. Traditional vermiculizers were mainly magnesium and rare earth. The former included magnesium titanium alloy, magnesium titanium aluminum, etc. The latter consisted of rare earth #1, rare earth calcium, rare earth magnesium, etc. With the development of vermicular graphite cast iron process, rare earth vermiculizer was widely used. Moreover, rare earth #1 had widest application. Inoculating aimed at chill elimination and microstructure refinement. The common inoculant was silicon iron. In addition, Ca, Ba and Sr inoculants were also used. In inoculant selection, thickness of casting was considered. E.g., Ca, Ba and Sr inoculants were suitable to thick casting. Complicated vermicular graphite cast iron process had great influence on performance. E.g., bad control of vermicularizing process will cause cast iron defects, cutting difficulty and tool break. In raw material smelting, temperature of melted iron reaches 1400-1480℃. Raw materials with low S content were selected to decrease consumption, thus ensuring high temperature, homogeneous composition, little impurity and pollution. Meanwhile, C, Si, P and S in melted iron should be stable to ensure the final component of cast iron. With suitable furnace pretreatment, vermicular graphite cast iron process can be improved to satisfy cutting quality.

3 ANALYSIS OF VERMICULAR GRAPHITE CAST IRON CUTTING

3.1 Research Situation of Cutting Process of Vermicular Graphite Cast Iron

In vermicular graphite cast iron, vermicular graphite structure exists in a state between spheroidal and flake graphite. The unstable structure results in the instability of vermicular graphite cast iron production. Cast structure is designed to increase iron content in cast iron. Vermicularizing and inoculating are applied to improve strength, toughness and abrasion performance of cast iron for a better quality and longer life. At present, the main problems of vermicular graphite cast iron process are machining efficiency, waste product and tool life. In cutting process, the broken parts of the tool are examined to derive reasons of tool break by experiences. Firstly, tool break is caused by unreasonable cutting parameters as well as overlarge speed of cutting tool and feed. Secondly, bad

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process control results in defects including blowhole, cast deficiency and hard spot. These defects will cause sudden increase of cutting force and tool break. Thirdly, the reasons of tool break involve the screw tap break caused by broken bit, as well as unfree chip removal and tool abrasion by broken tool in the bottom hole. Fourthly, overlarge unbalanced radial force at the exit will result in uneven cutting force of tool break. In addition, the port crack of broken tool should be conducted with careful examination and scientific analysis. The possible reasons are analyzed according to crack situation and fracture materials. The quality problems of cutter are eliminated at first. Then, cutting process of vermicular graphite cast iron is optimized.

3.2 Thinking of Improving Cutting Process of Vermicular Graphite Cast Iron

Vermicular graphite cast iron has a good thermal conductivity. Its expansion coefficient is higher than gray cast iron, and lower than high strength gray iron. With stable casting process and good castability, it can form compact and sound castings. However, some problems of cutting process result in the poor machining efficiency and high scrap rate. These problems are researched to optimize vermicular graphite cast iron process. Scientific experiments are performed to select reasonable cutting parameters. The cutting process is monitored to ensure complete bit, little tool wear, fluent chip removal and high cutting efficiency. Casting defects should be controlled. It is the key of vermicular graphite cast iron process. Firstly, vermicular graphite rate should be increased to prevent casting defects. Titanium is added to increase vermicular graphite rate in traditional vermicular graphite cast iron. However, the titanium carbide produced will weaken cutting performance. Certain Fe-Si-Mg alloy and residual Mg in melted iron contribute to increase of vermicular graphite rate and cutting performance. After performance estimation by total Mg content calculation, Mg addition in inoculant is determined to ensure performance of casting iron. Besides, vermicularizing effect can be improved by applying discontinuous reversed traveling wave magnetic field. Secondly, inoculation process should be controlled. Mg alloy and inoculant are added to eliminate chilling for microstructure refinement and performance improvement. There are many types of inoculation process. Thereinto, metal-stream and ladle inoculations are most widely used. In inoculation process, melted iron is sampled to determine amount of inoculant we use. Fracture should be examined to determine components. Thirdly, in thermal treatment, cutting performance of cast iron can be improved by eliminating casting stress and free cementite of thin wall. E.g., ferritizing annealing can be applied to improve plastic toughness and thermal conductivity, and eliminate free cementite of thin wall, thus increasing homogeneity, stability and processability. In addition, normalizing benefits the increase of pearlite content, cast iron strenght and abrasion resistance. However, the process is difficult to control. In a word, vermicular graphite cast iron process has characteristics such as complexity and changeability. The whole sections of casting process interrelate. E.g., vermicular graphite rate is determined by type and addition of vermiculizer. The production standard control of vermiculizer directly affects vermicularizing operation. Besides, inoculation is affected by vermicularizing. Consequently, careful research and experiments are required in each section of vermicular graphite cast iron process. The casting process should be emphsized to improve cutting performance, production efficiency and quality.

4 CONCLUSIONS

To improve cutting performance of vermicular graphite cast iron, we should focus on research of casting process and vermiculizer production standard. Vermicular graphite rate and inoculation quality are increased to ensure production stability and quality. Meanwhile, vermicular iron should be developed for a larger manufacturing application range and better cutting performance.

ACKNOWLEDGEMENT

The work was supported by Guangxi Natural Science Foundation Project (2014GXNSFAA118347); Science and Technology Cooperation Project of Yulin City and Guangxi University (201402801); Guangxi Key Laboratory of Manufacturing System & Advanced Manufacturing Technology Project (12-071-11S08).

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