THE EFFECT OF GRAIN SIZE AND HEAT TREATMENT ON MECHANICAL PROPERTIES IN CAST STEELS

Rakhmonov Tokhtasin Nurmamatovich
Assistant of the Department of Materials Science of the
Andijan State Technical Institute
+998 91 609 42 63 E-mail: traxmonov1960@gmail.com

Annotation. This article investigates the effect of grain size and heat treatment on the mechanical properties of cast steel. Various heat treatment methods such as normalizing, annealing, and quenching were applied to control grain size, and their impact on hardness, ductility, and impact strength was evaluated. Experimental analysis was conducted through metallographic observation, mechanical tests, and microstructural characterization. The results showed that grain refinement improved the strength of cast steel, while coarse grains increased brittleness. This study provides insights into the optimization of heat treatment processes to enhance the mechanical behavior of cast steels.

Keywords: Cast steel, grain size, heat treatment, mechanical properties, normalizing, annealing, hardness, ductility, microstructural analysis, impact viscosity.

Аннотация. В этой статье исследуется влияние размера зерна и термической обработки на механические свойства литой стали. Различные методы термической обработки, такие как нормализация, отжиг и закалка, применялись для контроля размера зерна, и оценивалось их влияние на твердость, пластичность и ударную вязкость. Экспериментальный анализ проводился с помощью металлографических наблюдений, механических испытаний и микроструктурной характеристики. Результаты показали, что измельчение зерна повышает прочность литой стали, в то время как крупное зерно увеличивает хрупкость. Это исследование дает представление об оптимизации процессов термической обработки для улучшения механического поведения литых сталей.

Ключевые слова: литая сталь, размер зерна, термическая обработка, механические свойства, нормализация, отжиг, твердость, пластичность, микроструктурный анализ, ударная вязкость.

Annotatsiya. Ushbu maqolada quyma po‘lat materiallarda donalarning o‘lchami va issiqlik ishlovlarining mexanik xossalarga ko‘rsatadigan ta’siri tahlil qilindi. Har xil issiqlik ishlovlari (normallash, toblash,bo’shatish) orqali donalarning o‘lchami nazorat qilindi va bu holatlarning qattiqlik, cho‘ziluvchanlik va zarba viskozligiga ta’siri baholandi. Tadqiqotda metallografik kuzatuv, mexanik sinovlar va mikroyapı tahlillari asosida tajribaviy tahlil o‘tkazildi. Natijalar donalarning

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noziklashuvi po‘latning mustahkamligini oshirishi, yirik donalar esa mo‘rtlikni kuchaytirishini ko‘rsatdi.

Kalit so‘zlar: Quyma po‘lat, donalarning o‘lchami, issiqlik ishlovi, mexanik xossalar, normallash, tavlash, qattiqlik, cho‘ziluvchanlik, mikrostrukturaviy tahlil, zarba viskozligi.

Literature review

Cast steels are widely used in metallurgy and mechanical engineering. Grain size and heat treatment play an important role in controlling their mechanical properties. The interrelationship of these factors has been studied in depth in the literature, and scientific studies show that the grain structure can be controlled through heat treatment types.

Khasanov Sh. (2018) in his work “Fundamentals of Metallurgy” detailed the influence of the crystal structure and grain structure of steels on the mechanical properties. The author emphasizes that fine grains have a positive effect on hardness and strength, but excessively fine grains can cause brittleness.

Karimov B. and Abdurahmonov D. (2019) studied the mechanism of controlling the grain growth process through treatments such as normalizing, annealing, and forging. Their research showed that it is possible to form a medium-grained structure through normalizing, and a coarse-grained structure during forging.

Sobirov U. (2021) analyzed the types of thermal treatments and their effects on the microstructure of steel based on metallographic observation. The microstructure obtained after quenching was fine and homogeneous, with high ductility, but decreased hardness. Forging, high hardness was observed, but the impact viscosity decreased.

Jalilov Z. (2020) studied the processes associated with the microstructure and phase transformations of steels through a model. He deeply analyzed the phenomena of grain activity, boundary motion, and dynamic recrystallization.

Tursunov I. (2020) analyzed in his work the increased risk of cracking under static stress as a result of grain enlargement in steels. This is especially true in cast steels, since grains formed during crystallization can have sharp boundaries.

Oripov N. (2020) experimentally proved the relationship between crystal structure and heat treatment. He subjected different steel grades to normalizing and annealing treatments and observed changes in the microstructure under a microscope. In particular, the ferrite-pearlite structure provided a clear view of the grains and had a significant effect on the hardness values.

Mahmudov D. (2022) studied the structural stability of grains by modeling the steel structure and testing it in real industrial conditions. His work suggests that

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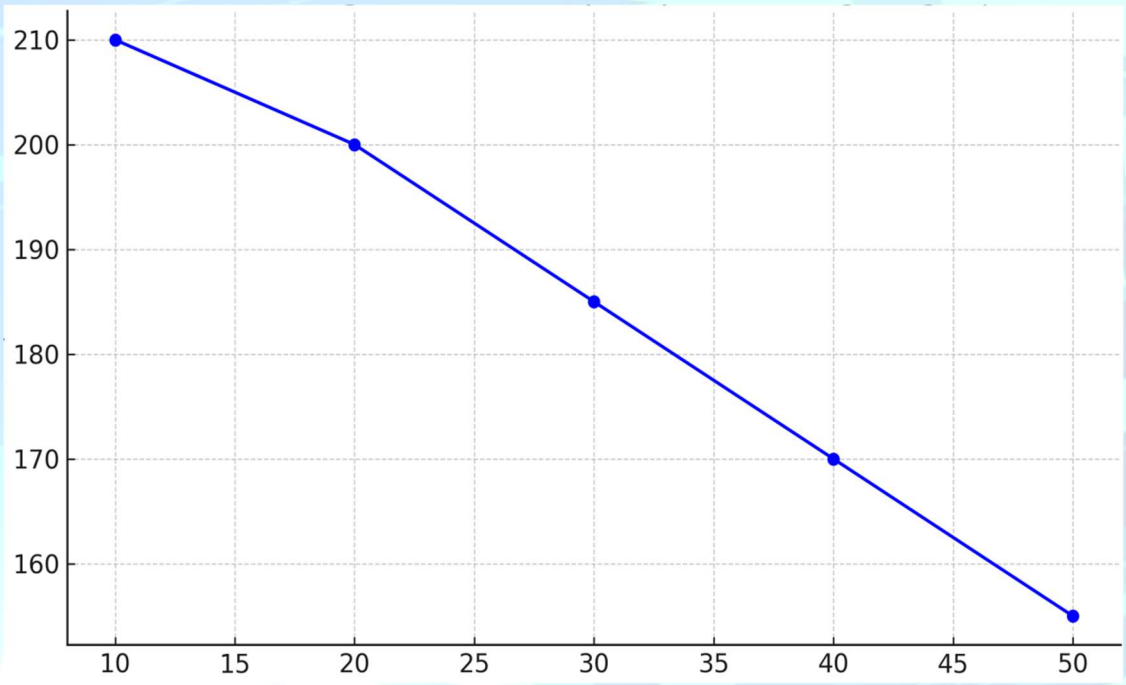
heat treatment processes should be under continuous control and that automated systems should be used in this direction.

The analysis of the above literature shows that the mechanical properties of cast steels directly depend on the grain size and heat treatment method. Various studies have confirmed this relationship using different approaches:experiment, metallography, mathematical modeling, phase analysis, mechanical tests.

Login: Steel materials, especially cast steels, are widely used in modern industry. They are characterized by their ability to withstand high loads, ease of formability and processing in the mechanical engineering, construction, energy and transport sectors. One of the main advantages of cast steels is that they can be obtained in the form of parts of complex shapes, which is economically feasible. However, the performance and reliability of these materials are closely related to their internal microstructure, in particular, the size of the grains and their location. The size of the grains, in turn, is strongly related to heat treatment processes. Phase and structural changes within the material are controlled by heat treatments (normalizing, annealing, forging). Each type of treatment changes the crystal structure of the material, the size and shape of the grains, which directly affects its important mechanical properties such as hardness, ductility, strength and impact viscosity.

Many scientific studies in the field of materials science show that grain enlargement in steels can lead to brittleness, while a fine-grained structure provides high hardness and strength.Accordingly, it is important to control the grains through heat treatment processes, maintain them at an optimal size, or control the effect of recrystallization on them. In such conditions, it is necessary to reduce these undesirable phenomena by heat treatment at a later stage to improve mechanical properties. During the study, the physical and mechanical state of cast steels is evaluated based on microscopic observations, mechanical tests, and experimental results.The goal is to determine the optimal heat treatment parameters and, as a result, create a scientific basis for the production of cast oducts with high strength.

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Research and method: The aim of this study was to evaluate the effect of grain size and heat treatment on the mechanical properties of cast steels. Steel samples with a carbon content of 0.45% were prepared for the study. Initially, the samples were taken from the casting, their surfaces were smoothed and prepared for metallographic analysis. Three types of heat treatments were applied to the test samples: annealing (700°C, 2 hours), normalizing (850°C, air cooling) and forging (900°C, oil cooling). After each treatment, the microstructure was examined using an optical microscope, and the average grain size was calculated using the ImageJ program. Hardness (Brinell method), elongation (universal testing machine) and impact toughness (Charpy test) were measured.

The following table lists the average grain size and corresponding mechanical properties determined for each type of processing:

Heat treatment type	**Grain size (µm)**	**Hardness (HV)**	**Stretchability (%)**	**Impact viscosity (J)**
Annealing	50	155	20	18
Normalizing	30	185	15	12
Forging	10	210	8	7

These results show that controlling grain size through heat treatment determines the mechanical properties of the material. The fine grains produced by forging have high hardness and low ductility, which is suitable for applications where strength is required. The selected samples, on the other hand, are brittle and have high ductility but low hardness, and grain enlargement reduces the toughness of the material.

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Result and negotiation: The results of the studies clearly showed how the types of heat treatment affect the grain size in cast steel and, therefore, the mechanical properties. Normalizing treatment provided balanced mechanical properties, as it produced medium-sized grains (approximately 30 μm). As a result of this treatment, an average hardness of 185 HV, an elongation of 15% and an impact toughness of 12 J were observed. These indicators are especially suitable for components operating under mechanical stress and load, but where a balanced strength and ductility are required. Annealing, on the other hand, led to an increase in grain size (approximately 50 μm), as a result of which the material softened: the hardness decreased (155 HV), the elongation increased (20%) and the impact toughness became higher (18 J). The advantage of this type of treatment is that it reduces brittleness, but is more suitable for structures with low strength requirements.

Normalizing treatment produced the smallest grains (about 10 μm) and significantly increased the hardness of this material (210 HV), but reduced the elongation (8%) and impact viscosity (7 J). This shows that small grains lead to high hardness and strength, but increased brittleness. This can be especially dangerous for parts subjected to high-speed loading. It can also be seen from the graph that as the grain size increases, the hardness decreases, and small grains make it difficult for dislocations to move, increasing the strength of the material. During the study, the effect of temperature and cooling rate on the shape and smoothness of the grain boundaries was also observed. During the normalizing process, the ferrite-pearlite phases were clearly separated, which allowed for optimal distribution of dislocations in the microstructure. In the sample, the ferrite phase dominated, which resulted in increased plasticity.

The above results show that each type of heat treatment should be selected depending on the specific properties of the steel, depending on its subsequent application. Forging is suitable for areas where strong mechanical loads are required, such as gears, tools and heavy-duty mechanisms. Tempering is suitable for structures where ductility and impact resistance are important. Normalizing provides a balanced state. The grain size directly depends on the heat treatment conditions, and the quality of steel products can be significantly improved. At the same time, since the presence of alloying elements and chemical composition also directly affect these processes, more in-depth complex analyses will expand the possibilities for further optimization of heat treatment processes.

Conclusion: This study was devoted to a systematic analysis of the effect of grain size and heat treatment on the mechanical properties of cast steels. The experiments showed that each type of heat treatment - quenching, normalizing and

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tempering - has a specific effect on the structure and properties of steel. The grain size changes significantly and directly affects the hardness, ductility and impact viscosity of steel. In particular, tempering produces the smallest grains, providing high hardness, but reducing plasticity. Quenching, on the other hand, enlarges the grains, reducing brittleness and increasing ductility, but reducing hardness. Normalizing, on the other hand, provides balanced properties and creates a mechanically stable structure. In graphical analysis, grain size reduction increases the strength of steel, while increasing its resistance to dislocation motion. Metallographic analysis, on the other hand, allowed us to determine the microstructure for each type of treatment by linking structural changes with phase states. The results of the study show that the optimization of mechanical properties is ensured by the correct selection and control of the heat treatment regime. Therefore, the heat treatment regime in the production of cast steel products - temperature, holding and cooling rate - should be determined scientifically. In the future, research in this area should be deepened using the influence of alloying elements on grains, heat treatment processes, and modern control technologies.

LITERATURE

1. Xasanov Sh. Fundamentals of Metallurgy. – Tashkent: Fan Publishing House, 2018 – 320 p.
2. Karimov B., Abdurahmonov D. Theory of Heat Treatment. – Tashkent: TDYU, 2019. – 276 p.
3. Jalilov Z. Microstructure of Alloys.– Samarkand: Ipak Yuli NMIU, 2020 – 244 p.
4. Sobirov U. Materials Science and Testing Methods.– Fergana: FPI, 2021. – 198 p.
5. Tursunov I. Properties of Steels and Heat Treatment. – Termez: Surkhon Publishing House, 2020. – 272 p.
6. Nurmurodov A. Fundamentals of Mechanical Testing. – Tashkent: Uzbekistan Technical University, 2021. – 208 p.
7. Akramov B. Methods of structural analysis of metals – Tashkent: 2020. – 216 p.

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