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The Use and Application of Lasers in Metallurgy

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Abstract: In this article, an analysis of selected studies on the physics of lasers and their application in metallurgy is presented, including a description of its scientific basis, discussion, and findings.

Keywords: Laser and the physics of lasers, application of lasers, and an increase in illumination through forced irradiation.

How does a powerful laser beam affect metal? This issue requires consideration of both scientific and practical importance. In order to achieve this, we must direct the laser beam towards the metal surface. Laser beam intensity will gradually increase, as the laser beam power can be increased and the focus of the light beam can be adjusted. If the intensity of the laser beam is at a value of 10^4 Vt/sm^2 or higher, then it can reach the melting temperature of any metal and cause it to melt. As the laser beam wears the metal surface, it will heat up and melt. The focal point where the light shines on the metal surface will eventually reach its highest temperature. Due to the thermal conductivity of the material, the lower layers of the metal will maintain a steady temperature during the heating process. As a result of the given beam intensity, the temperature on the surface rises. When the laser beam reaches an intensity of approximately 10^6 to 10^7 Vt/sm^2, the metal begins to boil. The laser beam will eventually circulate in that area upon ingestion by the metal, creating a plasma. The continuous increase in the laser's intensity makes it almost impossible for the laser beam to penetrate the metal surface. Therefore, it is important that the laser beam intensities in metallurgy are well-controlled. In terms of the duration of the laser pulse, it can be controlled by adjusting the frequency or the duration of the pulses. In order to prevent the heat from being conducted away from the area being worked on, it is important to ensure that the energy used by the laser is utilized by the material. In this case, the laser beam will consist of a separate pulse lasting 10^-7s. This allows a large amount of energy to be absorbed by the material during a short period of time, and it prevents the material from releasing significant energy onto its surrounding structure. Ultimately, the intensity of the laser beam on the material will be proportional to the energy absorbed by the material until it reaches its specific density. When speaking differently, the main part of the kinetic energy that is being stored in the matter is not spent on reaching the acceleration of the matter, but rather is spent on its spinning. Thus, it is reasonable to increase the time of the impulse in order to obtain a certain energy of the laser impulse. This will allow the opportunity to move towards the inner layers of the sample. Therefore, in working with the material, it is necessary to determine its energy and temporal characteristics based on its properties. In particular, for bonding, it is convenient to produce short pulses (lasting 10^-4 to 10^-5 seconds) with high intensity. Conversely, in order to melt the material, it is necessary to use long pulses with a low intensity (lasting from 10^-2 to 10^-3 seconds). What are the advantages of laser pointers? The wording "23 stones" can be seen in the "Polef" clock. Such inscriptions are also found in mechanical clocks. What do they mean? They move on the axis of the quartz stones on the dial, which is used as bearings in the clock mechanism. In order to make such bearings, it is necessary to produce a cylinder-shaped quartz rod of exact size in the rock, taking into account that the quartz is an extremely dense and hard material. Understanding how difficult this task is requires many years of experience and mechanical skills. The process of mechanical work, using the finger to support the job, lasted many years. Today, however, it is easy to cut quartz stones for clock faces using a "laser pointer". A solid-state laser, such as a neodymium glass laser, is used for the purpose of cutting these materials with a thickness of 0.5-1mm and an impulse length of 10^-4 seconds. The machine is capable of opening lacing in a single second. The performance of this laser machine is thousands of times higher than that of a modern mechanical machine. A technology has been developed for obtaining thin quartz tesserae from tungsten, brass, and other metals. For this purpose, very hard tools are used; the hardest among them is considered to be tungsten. Thus, the quartz tesserae that are used to extract the finest gold veins are produced using precisely this tool. But how can these tesserae be worked into an extremely hard material like gold? It takes 10 hours to make a mechanical tool for cutting such stones. This process can be simplified using high-power impulse lasers. This process is similar to that used in the manufacture of clock hands. First, the "raw" tesserae are made with a laser impulse, then polished with ultrasound, washed and given the desired shape. "Laser pointers" are not only used for heavy and hard materials, but also for very delicate materials. For example, microcircuits made of ammonium oxide ceramics can be etched. Due to the extreme brittleness of the ceramics, when processed by mechanical means, the ceramic is not shaped, but rather is fragmented in the cutter. The possibility of soldering microelectronics or its components in a chamber filled with inert gas generates significant interest because it prevents oxidation reactions and is closely related to the technology of manufacturing microchips. In this case, the use of laser light is particularly advantageous. Initially, laser light was only used for microsoldering. Using a YAG laser, the contacts of silicon wafers were soldered, and similarly, wire bonding operations were performed on thin wires. Later, CO2 lasers were used to determine the necessary dimensions of microchips. Currently, laser light is also used to adjust the parameters of microchips with thin metal layers during the production of specific parts of the circuit. It is worth noting that nowadays, laser light is extensively used to create resistor, capacitor, and inductive layer (multilayer) circuits. Laser light is also effectively used in producing special photo masks or templates for microchip components and in the selective removal of resist layers. In the mentioned cases, the material is heated by a powerful laser. For example, let's consider a microchip with a dielectric layer and a thin metal layer (conductor) on its surface. Focused laser light along the surface of the conductor is directed to create the required "pattern" of the microchip by selectively melting certain parts. As an example, let's introduce a continuously operating laser based on a neodymium-doped yttrium aluminum garnet crystal. The laser generates continuous light pulses with a wavelength of 400 nm. Each pulse lasts for 10^(-7) seconds, and the maximum power is 1 kW. The laser light is focused to such an extent that the diameter of the spot it produces is 10 micrometers. In the course of laser operation, the metal conductor on the surface of the chip is selectively melted.

During the engraving process, the laser beam moves along the surface at speeds up to 1 m/s. The focused light beam has a diameter of 0.2 mm. The movement of the laser beam and the engraving process are controlled by computer software. With the help of the machine, it is possible to engrave 50 pieces of engraved material within 1 hour. The engraving process is not only fast but also very precise. Additionally, the engraved material has a clean and sharp finish. Furthermore, laser light finds application in the aviation industry, particularly in the production of aerospace phase-shifting devices. Laser light is used to engrave titanium, steel, and aluminum sheets. With a power of 3 kW, a continuous-wave CO2 laser can engrave a titanium sheet with a thickness of 5 mm at a speed of 5 m/min. When the thickness is increased to 50 mm, the engraving speed decreases to 0.5 m/min. If oxygen is used instead of a laser, similar results can be achieved with a laser power of 100-300 W. How can we imagine laser technology in the present time? Modern laser technology encompasses various methods of material engraving, cutting, soldering, and marking. It is not limited to specific types of materials but offers versatility in processing techniques. The diversity of materials and applications in laser technology is truly remarkable. Laser light can be employed to work on any material in a precise and customized manner.

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