学 位 論 文 の 要 旨

Study on improvement of structure, mechanical and tribological properties of titanium by reaction diffusion
（チタンの反応拡散による組織，機械的およびトライボロジー特性向上に関する研究）

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This research discussed the structure, mechanical and tribological properties of pure titanium by boriding, oxidation, and nitriding with different processing temperatures. In addition, in order to further improve the wear resistance after oxidation, another substance such as carbon (using carbon fiber in this research) was added for processing at different temperatures to research the optimum experimental conditions. Moreover, the combined processing was carried out by boriding and nitriding, changes the processing temperature, and researches the best experimental conditions for combined processing by boriding and nitriding. In addition, combining the results of the wear testing (fatigue testing) and scratch testing (single point pressure testing), in order to analyze the performance of pure titanium at different processing temperatures.

Chapter 1 is an introduction. It introduces the necessity and purpose of this research, such as regular reports on surface hardening methods of boriding, oxidation, and nitriding, the effect of processing conditions on the properties of specimens, and analysis of the results of different surface modifications.

Chapter 2 describes the general experimental methods used in this research. In particular, the preparation of the surface hardened specimens and the evaluation methods of the properties after treatment are described in detail.

Chapter 3 describes the surface of pure titanium is treated by the dissolved salt dipping method to achieve the purpose of improving the surface hardness and wear resistance. Researched the effect of processing temperature (950°C-1150°C) for 2 h on the properties of treated specimens. The results show that the processing temperature has a great effect on the structure and performance of the treated specimen. This is due to the change in composition and the increase of the hardened layer at elevated processing temperatures. It can be seen from the experimental results that the fricative value of the treated specimen shows the smallest value at a processing temperature of 1050°C, with a value of 88.5 dB. With the increase of processing temperature, wear depth and wear width decreases gradually. The worn surface of the treated specimen by boriding at higher temperatures showed an excellent wear resistance during the designed processing temperatures. Based on these results, since the specimen at 1050°C processing temperature provides a high surface hardness, high peeling resistance, and low fricative value, it is considered to be the optimum condition.

Chapter 4 and Chapter 5 describe the mechanical and tribological properties of pure titanium by oxidation with different processing temperatures in the atmosphere have been investigated. Chapter 5 describes the properties of pure titanium treated by oxidation using carbon fibers. Comparing the results of these two chapters, it can be find that the presence and content of carbon fibers play an important role in improving the wear resistance of the specimens. It also can reduce the fricative value and coefficient of friction. As the processing temperature increases, the fricative value of the specimens decreases initially and then increases. When the processing temperature was at 850°C, the fricative value and coefficient of friction reached their minimum values, respectively. This surface modification was used in this present research substantially increased the wear resistance of pure titanium due to the formation of a hardened layer with high surface hardness. The reason why the wear resistance is improved by processing is not only the presence of oxides but also the presence of carbon fibers. It is due to the carbon fiber plays a self-lubrication and difficult adhesion. In addition, as wear testing time increases, part of the wear chips enters the dimples, which plays a role in inhibiting abrasive wear. In addition, the phenomenon of oxides whisker growth also plays a role in reducing wear.

Chapter 6 describes the properties of pure titanium treated by nitriding to improve the surface hardness and tribological properties. Based on the results of nitriding temperatures (850°C-1100°C) for 2 h on the properties of the pure titanium, some conclusions can be drawn in this research. Nitriding at all designed temperatures resulted in the formation of a compound layer consisting of nitride and oxides, where the relative fractions of the nitride and oxide depended greatly on the processing temperature by nitriding. After nitriding, the surface hardness of the specimen increases, and it first increases and then decreases with the increase of nitriding temperature. When the nitriding temperature is 1050°C, the surface hardness of the compound layer reaches the maximum value of 1792 HV. In addition, Young's modulus also reached the maximum at this nitriding temperature. The corresponding wear depth and wear width also reached a minimum at this nitriding temperature. Based on these results, when the nitriding temperature is 1050°C, the overall properties of pure titanium can be improved.

Chapter 7 describes the structure, mechanical and tribological properties of pure titanium by combined processing of boriding and nitriding with different processing temperatures in the heating furnace have been investigated. The specimen was treated by boriding at 1050°C for 2 h first and then treated by nitriding with different processing temperatures to evaluate the properties of treated specimens. Researching the effect of combined processing with different temperatures (1200°C-1400°C) on the composition and room temperature tribological properties of oxidized specimens. The results show that the surface hardness was increased first and then decreased as the processing temperature increased. When the processing temperature was at 1300°C, the surface hardness reached the maximum value. In addition, at this processing temperature, Young's modulus of the treated specimens was also showed a maximum value of 305.4 GPa during the designed processing temperatures. In addition, the wear depth and wear width were also got the minimum value at this processing temperature. Based on these results, since the specimen at 1300°C combined processing temperature provides high surface hardness and low wear resistance, it is considered to be the optimum condition.

In this research, a variety of surface modifications are used to study pure titanium at various processing temperatures. Regarding the results after the boriding, the specimen has a high surface hardness, and the surface hardness maximum value reached 2767 HV. Because of this, it is difficult to do secondary processing. In order to solve this problem, the properties of the specimens at different oxidation temperatures are discussed. From the results of oxidation, compared with the results of boriding, it is easy to do the secondary processing (surface hardness is 1005 HV), but it has a low wear resistance (wear depth is 10.7 μm). In order to solve this problem, the specimens were treated by oxidation using carbon fibers. From these results, it can be found that this surface modification can improve the wear resistance (wear depth is 2.01 μm), but it has a low peeling resistance (L_{C2} is 81 N). In order to solve this problem, the results of nitriding with different processing temperatures are discussed in this research. From these results, this surface modification can improve the peeling resistance (L_{C2} is 105 N). It also can get the coloration specimen, but it is difficult to do the secondary processing due to its high surface hardness (1792 HV). In order to solve this problem, the effect of combined processing temperature on the properties of the specimen was discussed. From these results, it can be found that this surface modification can make the specimen get comprehensive properties. Based on all of these results, suitable surface modifications can be chosen according to the practical applications.