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Research of MF series glass protective lubricant for titanium alloy precision forging process

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Abstract. Titanium alloy has high specific strength, high temperature resistance, corrosion resistance, excellent comprehensive performance and wide application, and most titanium alloy parts need to be forged, among which titanium alloy parts with complex structure need to be formed by precision forging. However, titanium alloy is prone to oxidation and gas permeation at high temperature, with large deformation resistance and narrow forging temperature range, so it is very important to solve the problems of protection, lubrication and heat preservation and heat insulation in titanium alloy precision forging. This paper mainly studies the working principle and preparation method of MF series glass protective lubricant for titanium alloy precision forging process, and its protective, lubricating and heat insulation effects on titanium alloy during heating and forging. It is found that the use of MF series glass protective lubricant for titanium alloy precision forging process can significantly improve the quality of titanium alloy precision forgings, showing good protective, lubricating and heat insulation effects.

Introduction

Precision forgings such as titanium alloy aircraft engine blades and artificial joints have complex shapes, and the machining allowance after forging is small. Even some parts need to be precision forged without allowance, and strict three-coordinate testing and mechanical properties testing are required after forging, so the quality of forgings is very high. It is found that the quality of titanium alloy precision forgings can be significantly improved by using glass protective lubricant during the forging process. Specifically, the glass protective lubricant can produce good protective, lubricating and isolating effects in the whole process of forging heating and forging, which can prevent the billet from oxidation and hydrogen absorption at high temperature, delay the temperature drop of forging and reduce the deformation resistance during forging, and isolate it from the die, thus prolonging the service life of the die[1-8].

Formulation design of MF series glass protective lubricant for titanium alloy precision forging process

The glass protective lubricant used in titanium alloy precision forging process is a suspension prepared by ball milling with a variety of amorphous composite glasses as the main solid base and a certain amount of crystalline fillers, adhesives, additives and water. Before the titanium alloy blank is heated in the furnace, the coating is evenly stirred and sprayed on its surface, and the coating is formed after drying. When designing the coating formula, we should consider the specific thermal system of titanium alloy, that is, heating temperature, holding time and furnace atmosphere, and design a coating with good compatibility and appropriate high-temperature viscosity and expansion coefficient, so as to achieve a perfect match with the corresponding thermal system.

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(1) Amorphous composite glass powder

As the most important substance in coatings, glass powders with different softening temperatures, high-temperature viscosities and different particle sizes are used in coatings to form amorphous composite glass powders. Among them, the glass powder with low softening temperature will quickly melt and form a film when the alloy is heated in the furnace, so as to isolate the oxidation of the alloy matrix by harmful gases such as O_2. With the increase of alloy temperature, the glass powder with higher softening temperature gradually melts to form a film, so that the coating can remain dense, uniform and stable at high temperature and isolate harmful gases. During forging, the glass powder that has melted into a dense and closed film on the surface of the blank can play a good role in lubrication, reduce the deformation resistance of titanium alloy, facilitate the forming of forgings, isolate it from the die and prolong the service life of the die.

At present, the realization of glass components with different softening temperatures and high-temperature viscosities is mainly achieved by adjusting the chemical composition of glass. For example, increasing SiO_2, Al_2O_3, MgO and other compounds in glass components can increase the high-temperature viscosity of glass, while increasing TiO_2, Na_2O, K_2O, B_2O_3 and other compounds in glass components can reduce the high-temperature viscosity of glass. The viscosity changes of glass powder at different temperatures are detected by a high-temperature viscometer to determine the optimal viscosity range.

(2) Crystalline filler

Specifically, crystalline fillers mainly include SiO_2, Al_2O_3, ZrO_2, kaolin and other substances with high temperature resistance, stable chemical properties and no high-temperature thermal corrosion to titanium Al_2O_3, so as to enhance the high-temperature stability of the coating.

(3) Binder

The binder in the coating directly affects the adhesion of the coating on the blank after spraying or brushing, and good adhesion can make the coating not easy to fall off after drying. At the same time, a good binder should also ensure that the coating is easy to wash after drying, so that the coating can be easily removed when there is an error in coating and the blank will not be scrapped. The selected binder should also be non-toxic and non-irritating to ensure the environment of the spraying site. According to the above requirements, this coating adopts environmentally-friendly waterborne acrylic emulsion binder, which can ensure the adhesion of the coating on the blank, ensure that the coating is easy to wash, and help to enhance the suspension performance of the coating, and avoid the problems of precipitation and delamination of the coating after long-term storage.

(4) Additives

This coating draws lessons from the design concept of architectural coating formula, and adds multifunctional additives such as wetting agent, defoamer, film-forming additive, thickener and dispersant, which adjusts the viscosity of the coating to a more suitable range and improves the comprehensive performance of the coating.

Adhesion of MF series glass protective lubricant for titanium alloy precision forging process

The MF-T21 glass protective lubricant for titanium alloy precision forging process was prepared through the above ideas. MF-T21 glass protective lubricant with different thickness was sprayed on TC4 titanium alloy with the same surface state, and its adhesion was tested by PosiTest AT-M drawing coating adhesion tester in the United States. According to the test experience, the coating adhesion can meet the requirements when it reaches more than 0.6MPa, that is, it can ensure that the blank will not fall off during the transportation after spraying and drying. The test results are shown in Fig. 1.

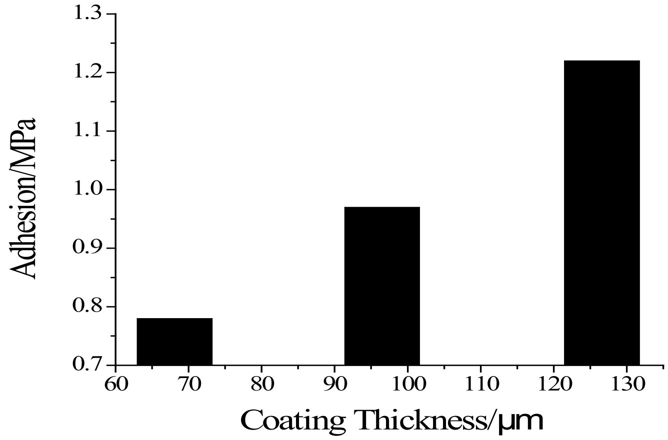
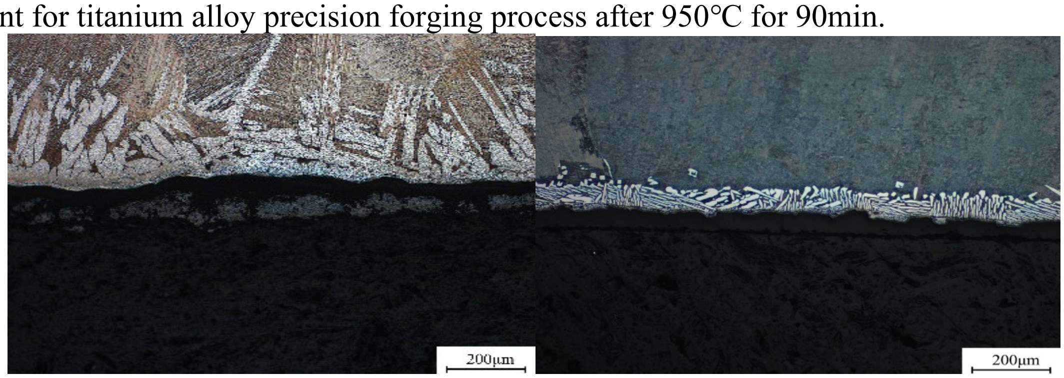


Fig. 1. Adhesion of glass protective lubricant for MF-T21 titanium alloy precision forging process.

As can be seen from Fig.1, the adhesion of the binder added in MF-T21 glass protective lubricant increases with the increase of coating thickness, and both are greater than 0.6MPa. It can be seen that MF-T21 glass protective lubricant can be well adapted to spraying with different thicknesses in the production site, and can be firmly attached to the surface of titanium alloy after spraying and drying.

Protective performance of MF series glass protective lubricant for titanium alloy precision forging process

In order to verify the high-temperature protection effect of glass protective lubricant for MF-T22 titanium alloy precision forging process on titanium alloy, TC4 titanium alloy was selected for the high-temperature protection effect experiment. Fig. 2 shows the micro-morphology of TC4 titanium alloy bare material and TC4 titanium alloy sample coated with MF-T22 glass protective lubricant for titanium alloy precision forging process after 950℃ for 90min.



(a). 950℃/90min, uncoating; (b) 950℃/90 min, coating MF-T22

Fig. 2. Microstructure of oxide layer of TC4 titanium alloy.

As can be seen from Fig. 2, the thickness of α oxide layer on TC4 titanium alloy sample coated with MF-T22 glass protective lubricant is obviously reduced compared with that of bare material, and the anti-oxidation effect is obvious. At the same time, the coating can still firmly adhere to the surface of titanium alloy after the sample is cooled, which shows that the expansion coefficient of the coating is well matched with that of TC4 titanium alloy.

Lubrication performance of MF series glass protective lubricant for titanium alloy precision forging process

In order to determine the lubrication effect of MF-T22 glass protective lubricant on titanium alloy at high temperature, the friction coefficient (μ) difference between TC4 titanium alloy surface coated with MF-T22 glass protective lubricant for precision forging process at different temperatures was measured by ring upsetting experiment on a 630-ton hydraulic press.

The specific experimental conditions are as follows: the upper and lower backing plates with roughness of 0.6μm are installed on a 630-ton hydraulic press, and the backing plates are heated to 400±20℃ before forging, and the dimensions of titanium alloy rings are-20±0.2 mm in outer diameter, 10±0.2 mm in inner diameter and 7±0.2mm in height. The TC4 titanium alloy sample is heated by a box-type electric furnace, and the pressing speed of the press is 3mm/s during forging. The coated and uncoated titanium alloy samples were forged at three temperature sections of 930℃, 950℃ and 970℃ respectively, in which five parallel samples were set at each temperature section. The experimental results are shown in Table 1 and Table 2. According to the experimental data, the average compression ratio and inner diameter reduction ratio of TC4 titanium alloy samples can be calculated, and then the corresponding friction coefficient μ can be found by the theoretical correction curve of measuring friction coefficient by ring upsetting method.

Table 1. Experimental results of ring upsetting of TC4 titanium alloy samples without MF-T22 glass protective lubricant coating.

Heating temperature(℃)	930	950	970
Deformation (%)	31	28	32
Height after compression (mm)	5.4	5.3	5.2
Compression ratio (%)	23	24	26
Internal diameter after compression (mm)	8.2	8.3	8.4
Inner diameter reduction rate (%)	18	17	16
Friction coefficient(μ)	0.57	0.53	0.48

Table 2. Experimental results of ring upsetting of TC4 titanium alloy samples coated with MF-T22 glass protective lubricant.

Heating temperature(℃)	930	950	970
Deformation (%)	34	32	31
Height after compression (mm)	4.8	4.7	4.6
Compression ratio (%)	31	33	34
Internal diameter after compression (mm)	8.5	8,6	8.7
Inner diameter reduction rate (%)	15	14	13
Friction coefficient(μ)	0.26	0.19	0.20

After calculation and analysis, the friction coefficient of the sample without glass lubricant is 0.48 ~ 0.57 when forging at high temperature. However, the friction coefficient decreases to 0.19~0.26 with glass protective lubricant. This is mainly because the glass protective lubricant coating forms a uniform, dense and closed molten glass film at high temperature, which can separate the forging from the die, thus changing the solid-solid contact into the solid-liquid contact, that is, changing the external friction between the forging and the die into the internal friction between the molten glass, and playing a good lubrication effect. Furthermore, the influence of lubrication on forging production is comprehensive, not limited to reducing the friction between

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workpiece and die contact surface, reducing deformation resistance and improving die life. Good lubrication can also save equipment energy and forging materials, improve equipment life and forging performance.

Conclusion

To sum up, MF-T22 series glass protective lubricants for titanium alloy precision forging process can form a uniform, dense and closed glass film during the heating process of titanium alloy blank, which can protect titanium alloy at high temperature and play a good lubrication role in the forging process of titanium alloy blank. At the same time, due to the low thermal conductivity of glass, it can play a good role in heat preservation of the blank, ensuring that the titanium alloy blank maintains a low deformation resistance for a long time during forging, which is a powerful guarantee for obtaining excellent quality titanium alloy precision forgings.

References

[1] C.C. Cojihiieb, A.T. Tymahob, Protection Coating for Metals Heating (Beijing: China Machine Press), 1979.

[2] C. Ding-chun, C. Jiang, Effect of Glass-protection Lubricants on Oxidation Resistance Behavior of TC6 Titanium Alloy, Hot Working Technol. 4 (2016) 121-123.

[3] W. Lian-jun, M. Chang-gong, The Study of Protection Coatings for Titanium Alloys at High Temperature, Rare Metal. Mater. Eng. 32 (2003) 151-153.

[4] C. Ming-hui, S. Ming-li, Effect of Sand Blasting and Glass Matrix Composite Coating on Oxidation Resistance of a Nickel-based Superalloy at 1000℃, Corrosion Sci. 73 (2013) 331-341. https://doi.org/10.1016/j.corsci.2013.04.022

[5] C. Ming-hui, L. Wen-bo, Glass Coatings on Stainless Steels for High-temperature Oxidation Protection: Mechanisms, Corrosion Sci. 82 (2014) 316-327. https://doi.org/10.1016/j.corsci.2014.01.033

[6] W. Le-an, Manufacturing Engineering for Hard Wrought Alloy Forgings (Beijing: Nation Defense Industry Press), 2005.

[7] W. Shu-yun, D. Su-jie, Study of Glass-protection Lubricants for Stainless Steel Forging, Forging & Stamping Technol. 34 (2009) 8-10.

[8] D. Su-jie, L. Xi-chun, T281 Environment-friendly and Air Resistant Glass Lubricants for Precision Forging of Titanium Alloys, Forging & Stamping Technol. 35 (2010) 114-116.