Study on the Influence of Process Parameters on Grain and Phases of TC4 Ti-alloy Forging

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Abstract. By using the finite element software, the thermal process of TC4 Ti-alloy large die forging two beam is analyzed, the influence of billet initial heating temperature and compressor speed on the distribution of grain and phase is revealed. The research shows that fine and uniform microstructure will be obtained when the billet initial heating temperature is 980°C and at the same time compressor speed scheme of two straight ladder variable loading is used.

Introduction

TC4 Ti-alloy (nominal component Ti-6A1-4V) is a kind of (α+β) two phase titanium alloy, which has a good process plastic, superplastic, welding and corrosion resistance etc. So it is widely used in aviation, aerospace, chemical industry and other industries [1-3]. During the high temperature forging process of TC4 Ti-alloy, dynamic recrystallization will occur, and new grains will generate. The evolution of microstructure will largely determine the macro mechanical properties of the forging. Because the occurrence of dynamic recrystallization is associated with forging temperature and deformation in the process, the dynamic recrystallization grain size can be controlled by using different deformation parameters of thermal process, and the microstructure can be refined. It is an important method to improve the mechanical properties of TC4 Ti-alloy forging. The study shows that the dynamic recrystallization grain size and the percentage of recrystallization grains are mainly determined by the temperature, strain and strain rate of the deformation and cooling process, in addition to the original grain size and the content of trace elements. So the effects of initial heating temperature and press speed on the microstructure of the billet are studied.

Test

Test Materials.

Basic dimensions of TC4 Ti-alloy large forging two beam are 3512mm × 138mm × 276mm, volume is about 47861890mm^3, and the forging process is carried out on the 800MN hydraulic press.

Test Scheme.

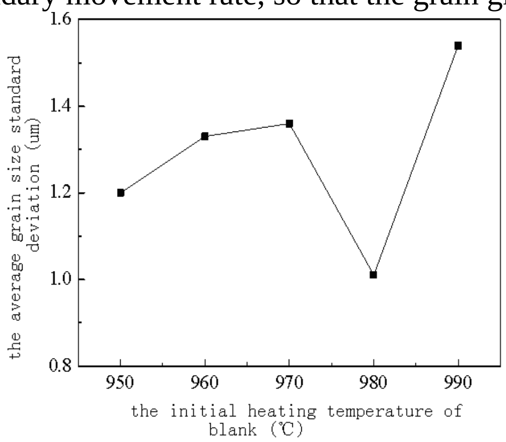
In the temperature range of 950°C to 990 °C, 950°C, 960°C, 970 °C, 980°C and 990°C are selected as initial heating temperature of the billet. And compressor speed is used five kinds: 4mm/s, 8mm/s, 12mm/s, 16mm/s and 20mm/s in the first fire. Parameters are shown in Tab.1.Because there are many factors in the selection, the selection and setting of the initial heating temperature of billet and compressor speed in the second fire are determined according to the simulation results of the first fire, in order to reduce the number of simulation tests.

Tab.1 Design of simulation test parameters in the first fire

Test number	Blank temperature (°C)	Compressor speed (mm/s)	Test number	Blank temperature (°C)	Compressor speed (mm/s)
1	950	4	14	970	16
2	950	8	15	970	20
3	950	12	16	980	4
4	950	16	17	980	8
5	950	20	18	980	12
6	960	4	19	980	16
7	960	8	20	980	20
8	960	12	21	990	4
9	960	16	22	990	8
10	960	20	23	990	12
11	970	4	24	990	16
12	970	8	25	990	20
13	970	12			

Test results and Discussion

The effect of initial heating temperature on grain and phases. The forging temperature, the average grain size, α phase volume fraction and the standard deviation are shown in Fig.1 in the simulation test of the first fire (before cooling). It can be seen from the Fig.1, with the increase of temperature, the average grain size of the forging maintains an upward trend on the whole, but at 980°C , the average grain size suddenly decreases, then suddenly increases. The grain size also increases, which is mainly due to the increase of temperature, grain boundary activity and the grain boundary movement rate, so that the grain growth rate increases.



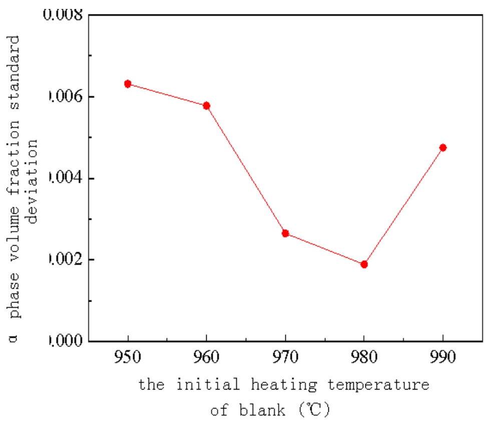


Fig. 1 The average grain size and α phase volume fraction standard deviation in different temperatures

When the temperature is 980°C, the average grain size standard deviation, α phase volume fraction standard deviation are both taken to the minimum value, which shows that the forging can get the most uniform grain distribution and phase distribution. At 980°C, the different phenomenon analysis which is not the same as change trend is due to the appearance of local near β forging in the forging process(The forging is carried out at 15°C below the phase change point)[4-6]. It is because that the forging temperature decreases in the process of billet transport and the mold space travel, the surface temperature will be reduced to 750°C . But the core temperature decreases slowly, and energy convert in the forging process. So when a local temperature rises to about 975°C , a near β forging will occur and the fine and uniform grain will be got.

The effect of compressor speed on grain size and phase. Because better organization can be obtained at the initial billet heating temperature of 980°C , the second fire billet heating temperature should be set directly for 980°C .Compressor speed is used five kinds: 4mm/s, 8mm / s, 12mm/s, 16mm/s and 20mm / s in the second fire. Test parameters are set as shown in Tab.2.The influence of compressor speed on the microstructure parameters in the second fire is shown in Fig.2.

Tab.2 Design of simulation test parameters in the second fire

Test number	26	27	28	29	30
Press speed(mm/s)	2	4	6	8	10

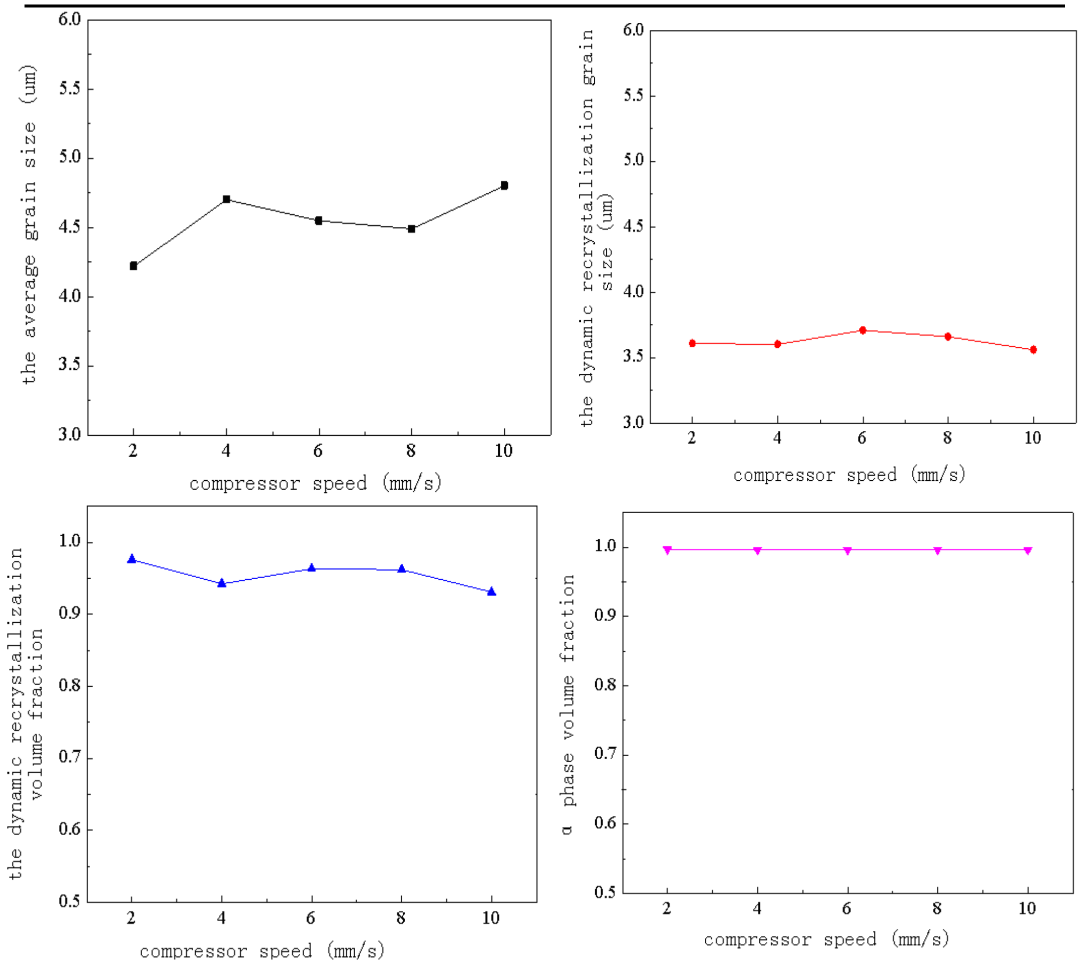


Fig. 2 The effect of compressor speed on grain size and phase in the second fire

As can be seen from Fig.2, the effect of compressor speed on α phase volume fraction is very small, but the dynamic recrystallization volume fraction has different results. The dynamic recrystallization volume fraction distribution in the second fire is much wider than that of the first fire, and the differences between them are also revealed. Dynamic recrystallization volume fraction decreases first and increases after, then keeps decreasing trend as compressor speed from 2mm /s to 6mm /s. This is mainly because die trip is short, forging process is also short, the deformation is small, parts of forging region are too late to occur dynamic recrystallization or can’t reach the critical strain, the dynamic recrystallization is unable to be completed in the second fire.

The uniform and fine grain and relatively uniform phase distribution are got when compressor speed is 2mm /s. But because compressor speed is too low, forging process is relatively long, temperature decreases largely, and the temperature field distribution is not uniform, the deformation resistance increases dramatically, so as to make the mould load to 7.58 million tons. This has been close to the limit load capacity of the equipment, and it should be avoided as far as possible. When the press speed is 8mm/s, the uniform and fine grain, more uniform temperature distribution and the moderate mold load are obtained, which are suitable for the second fire forging process.

Optimization of speed loading scheme for press. Because the blank heating temperature range is very narrow, the temperature control is not very flexible, the optimization of billet heating temperature doesn’t have great practical significance. And for 800MN hydraulic machine, speed loading scheme can be very flexible. Because of the final performance of forging depends on the second heat forging process, compressor speed loading scheme in the second fire is mainly optimized.

By designing six kinds of variable load mode which include curve type, linear type, curve and linear hybrid, secondary ladder line type, three level ladder line type, three hybrid ladder type, and by simulating 2 ~ 4 kinds of speed scheme for each speed loading mode, a total of 20 groups of simulation and optimization tests are conducted. Through statistical analysis of the simulation results, it can be obtained that the variable loading scheme can obviously improve the forging microstructure. It is shown as Fig.3.For the convenience of research, it is set to (a), (b), (c), (d) program. The optimization results which are obtained from the four optimization schemes are shown in Tab.3.

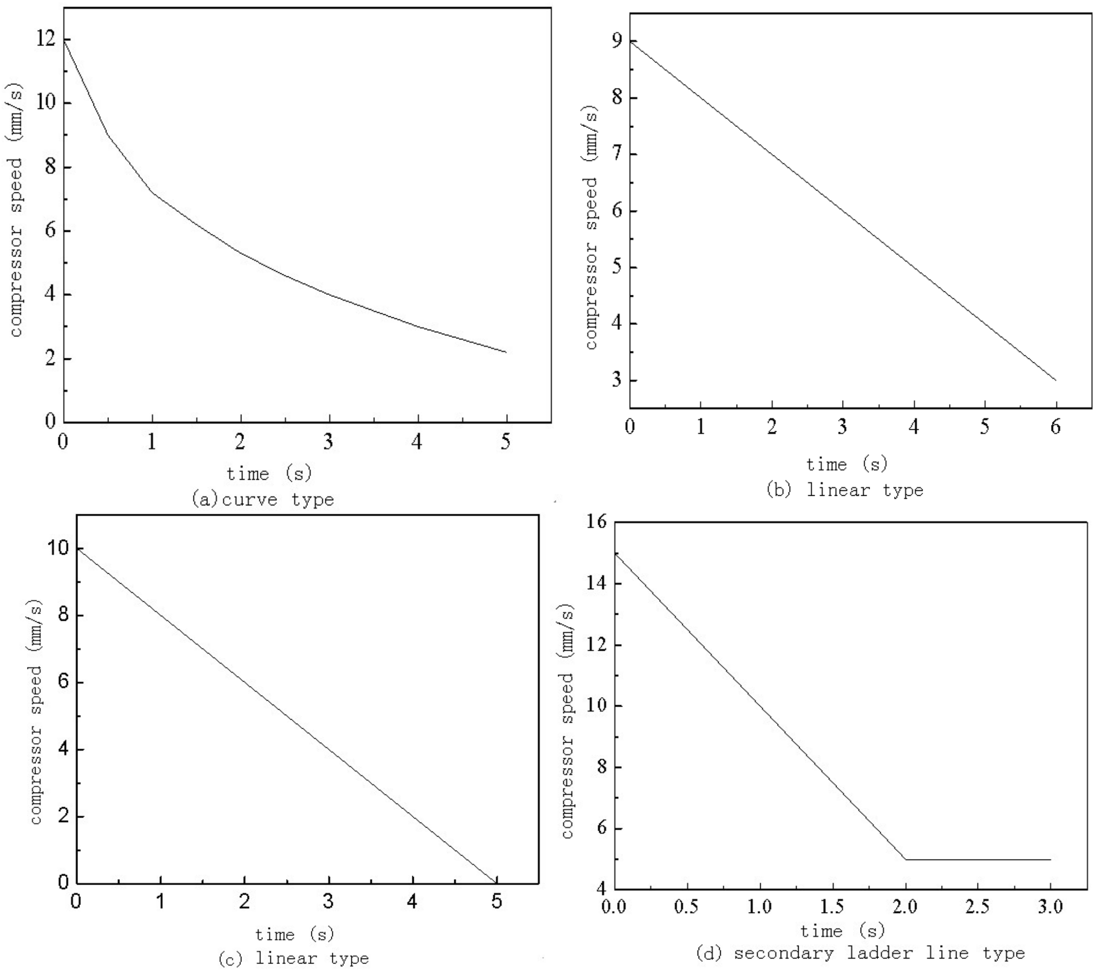


Fig.3 The optimized speed loading schemes

It can be obtained from Tab.3 that the four group optimization schemes based on the original scheme have a better optimization effect. By using D scheme as the best plan, the minimum load, the most uniform temperature and phase distribution are obtained. But if the press speed is too fast, the deformation will be inhomogeneous and he forging structure will also be inhomogeneous.

When the press speed is slow, it is more conducive to obtain uniform organization, but the grain will be relatively bulky.

Tab.4 The optimized results obtained by the optimization method (S.D. represents the standard deviation of the previous column of data in the table)

	The average temperature of forging(°C)	S.D. (°C)	The average grain size(μm)	S.D. (μm)	α phase volume fraction	S.D.	Die load (ten thousand tons)
Original scheme	801	111	4.49	3.01	0.996	0.00314	6.19
A scheme	809	101	4.23	2.56	0.998	0.00162	6.47
B scheme	817	94.9	4.39	2.88	0.998	0.00137	6.74
C scheme	815	102	4.42	2.87	0.998	0.00166	6.75
D scheme	824	92.6	4.3	2.92	0.998	0.00135	6.16

Conclusions

(1)When the initial heating temperature of billet is 980°C ,the fine and uniform grains can be obtained. This is because the local area of the blank appears near β forging.

(2)By using the variable speed load mode of secondary ladder line type, the small and uniform structure can be obtained. This is because the fast press speed is able to get small grain, the volume fraction of β phase will increase.

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