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Deformation Behaviour and Microstructure Evolution of Titanium Alloys with Hot Working Process

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Abstract: The behaviour of the high-temperature deformation mechanism of titanium alloys at different temperatures and strain rates and the associated changes in the microstructure have been studied. In addition to good heat transfer properties, titanium has a low density, can be reinforced with alloys, and can be deformed and formed to increase strength. Titanium is non-magnetic and a good conductor of heat. Its coefficient of thermal expansion is slightly lower than that of steel and less than half that of aluminium. Titanium's combination of mechanical and physical properties, as well as its resistance to corrosion, m ake it an ideal material for critical applications in the aerospace, industrial, chemical and energy sectors. It has been found t hat the appropriate parameters of the titanium deformation process are different temperature conditions and strain rates. The influence of the micro-structural properties of the deformed specimen was studied and correlated with the test temperature, total strain and strain rate to develop a constitutive equation for the relationship between yield strength, strain rate and temperature. Micro-structural studies were performed on the sample and the results analysed..

Index Terms: Titanium Alloy, Hot Compression Test, Different Temperatures, Different Strain Rates

I. INTRODUCTION

Titanium alloys were developed for better formability and machinability. Because of its good formability and machinability, th is alloy is widely used in military and civil fields such as aviation, medical equipment, etc. [1]. In recent years, map processing technology based on dynamic material model theory has found wide application in studying the structure, function and deformation mechanism of metallic materials [2]. This ability can reflect the microstructure evolution and evolution mechanism of alloy materials under various molding conditions, optimization and ensure the maximum of ther mal material deformation proc ess parameters, thereby civilizing machining ef ficiency, controlling microstruture evolution, and avoiding hot working defects [3]. Titanium alloys are currently used for demanding applications such as stationary and rotating parts of gas turbine engines. Some of the most critical and stressed civilian and military parts of the air frame are made from these alloys. In recent years, the use of titanium has expanded to include applications in nuclear power plants, food processing plants, oil refinery heat exchanges, marine components and medical implants. The compression test determines the behavior of materials under pressure. The sample is compressed and the elongation under various loads is recorded. Compressive stress and strain are calculated and plotted as a stress-strain diagram, which is used to determine yield strength, proportional strength, yield strength, yield strength, and for some materials, compressive strength as well. The hot compression test can be conveniently used to test the plastic deformation of a material under various temperatures and strain rate conditions.The influence of microstructural properties of the deformed specimen can be studied and correlated with the test temperature, total strain, and strain rate to develop a constitutive equation for the relationship between yield strength, strain rate, and temperature.

II. LITERATURE REVIEW

Isothermal and constant compression tests of a titanium alloy are carried out with the thermal simulator under conditions of a strain temperature of 700 to 950°C and a strain rate of 0.001 to 1s-1. When the elongation is 0.9, the elongation rate is greater than 0.5 when the elongation temperature is 800°C and the elongation rate is 0.001s-1 and 1 s-1. Under these conditions, titanium alloy SP700 can undergo super-plastic deformation. In addition, the analysis shows that at a deformationtemperature betw een 775 and 825°C,the deformation rate is between 0.3 and1 s-1 and between 0.001 and 0.002 s-1, this condition is the best machining parameter range for the titanium alloy SP700 [4]. The hot formability of Ti-6Al-4V was tested by hot compression tests performed in the temperature ranges 880, 900, 920, 940, 950 °C and at strain rates of 1, 15 and 50 s-1.

The influence of the micro-structural properties of the deformed samples was investigated and correlated with temperature, total strain and strain rate. The material equation of yield strength was defined and the test conditions for uniform deformation were eval uated.

The machine used for the tests made it possible to obtain very large deformations through uniform compression with long defor mations, while the data from the scientific literature are clearly limited in comparison. In this way, greater precision in m odeling the behavior of materials could be achieved [5].

The compression experiment of a hot-rolled Ti-55 alloy was performed in the temperature range of 700–1050 °C and a strain rate in the range of 0.001 to 1 s-1. The hot working behavior and machinability of the rolled Ti-55 alloy were studied and optimized hot working parameters were determined by analysis of microstructure evolution and determination of hot workability.

The behavior of the hot deformation and the evolution of the microstructure during the thermal compression were analyzed.The results show that the apparent activation energies of the two-phase region and the monophasic region were calculated to be 453.00 KJ/mol and 279.88 KJ/mol, respectively [6]. The hot compaction of a titanium alloy was investigated using finite element simulation and the results compared the experimentally obtained results. Based on the results of the ring compression t est, the constitutive behavior of the material and the friction at the extrusion temperature are determined. Effective strain, temperature and stress distributions were simulated under different design and process conditions. The simulation resu lts indicate that heat generation from deformation is important in hot extrusion of titanium alloys and occurs mainly at the beginning of the extrusion process. This leads to a reduction in yield stress, which in turn leads to a widening of the deformation zone. Sufficient agreement was found between the experimental results and the results of the simulation [7] . The hot elongation test of a commercial Ti-6Al-4V alloy with an initial lamellar microstructure is performed in the temperature range of 750 to 11 00 °C in 50 °C increments and strain rate ranges of 0.0003, 0.001, 0.01, 0, 1, 1 and 10S-1 tested to model macro structural e olutionn. The application of these results to the design of bulk metalworking processes to achieve macrostructural control is also discussed [8]. Hot compression tests performed on Ti-6Al-4V near the transus and over a wide range of strain rates from 0.001 to 100s-1 indicate that the former strain rate causes a significant change in the phase transition mechanism. The evolution of the equiaxed morphology after deformation at high strain rates has been explained based on dislocation-assisted precipi tation model [9]. Based on the observations of the microstructure of titanium and its alloys contain ned in the literat ure, it has been proposed to limit the machinability parameters for the localization of flows or cracks that occur during the hot deformation of materials. The specified limit of machinability parameters is verified by considering yield stress data and micro-structural observa ions of titanium alloys [10].

The changes in the microstructure of the β-titanium alloys Ti-15V-3Cr-3Sn-3Al and Ti-10V-2Fe-3Al and the titanium alloy Ti-6Al-4V during hot deformation at temperatures in two-phase zones were investigated. For β-titanium alloys, dynamic recovery occurs m ainly under stress in the single-phase β regime, although discontinuous dynamic recrystallization occurs along the β-grain boundaries. The size and proportion of the recrystallized β-grains increase with decreasing strain rate or increasing strain temperature [11]. Self-developed titanium alloy Ti-35421 is a new type of low-cost, high-strength titanium alloy. In this study, to understand the hot behavior of the Ti-35421 alloy, isothermal compression tests were performed over a st rain temperature range of 750 to 930 °C with a strain rate range of 0.01 to 10 s-1. Electron backscatter diffraction was used to characterize the microstructure before and after thermal deformation. The results show that the stress-strain curves show a clear el astic behavior at high strain rates. With the increase in the deformation temperature and the decrease in the deformation rate from , the α-phase content gradually decreases. The EBSD analysis showed that the volume fraction of recrystallised grains was very low, so dynamic recovery is the dominant strain mechanism in Ti-35421 alloy. Besides DRV, the alloy Ti-35421 is found more frequently in continuous dynamic recrystallization than in discontinuous dynamic recrystallization [12]. Titanium alloys are widely used in many industries such as automotive, aerospace and biomedical due to their excellent general purpose properties. A well-designed multi-step thermomechanical treatment is essential in the manufacture of tita nium components to obtain fine microstructures and favourable properties. In the manufacture of titanium components, sub-transus machining is an important step in breaking up the fine-grained flake microstructure in the hot-working process, and thus plays a key role in customizing the microstructure and final properties. To achieve this goal, significant efforts have been expended to study the mechanisms of evolution of microstructure and flow behavior during sub transprocessing. This arti cle reviews recent advances in experimentation and modeling aimed at providing guidance to the titanium alloy research community on process design and microstructure tuning. Platelet globalization is analysed in detail from three aspects, name ly the mecha nism of globalization, heterogeneity and kinetics. Then typical features of the flow behavior and explanations for a significant flow softening are summarized.

Recent advances in modeling microstructure evolution and flow behavior in subtrans processing were also presented. Current pr oblems and challenges in understanding the microstructure evolution and flow behavior of titanium alloys with lamellar microstructure have been presented and identified in their future studies [13].

The thermal deformation behavior of the titanium alloy Ti-6Al-4V (TC4) was investigated in the temperature range from 650°C to 950°C with a strain rate between 7.7×10^{-4} s^{-1} and 7.7×10^{-2} s^{-1}. The results of the hot tensile test show that the yie ld strength decreases with increasing strain temperature and increases with increasing strain rate. The result of the XRD analysis shows that only the deformation temperature affects the phase composition. The evolution of the microstructure under different strain conditions was characterized by TEM observations. In low temperature deformation of TC4 alloy, work ha rdening dominates, while at high temperature dynamic recovery and dynamic softening assisted recrystallization dominate [14].

III. EXPERIMENTAL PROCEDURE

This article investigates the hot deformation behavior of a titanium alloy (Ti-6Al-4V) at different strain rates and temperatures using a hot compression test. The influence of various important parameters of the hot compression test, such as temperature and strain rate, is investigated. Performing a hot compression test at different strain rates and temperatures. Develo pment of the workpiece after processing in the microstructure test. Hot press specimens 12 mm high and 8 mm in diameter machi ned the part. A hole 1 mm in diameter and 5 mm deep was drilled in the centre of the sample to insert a thermocouple, which was used to measure the actual temperature of the sample and any temperature rise during the test.

The hot compression testing was performed using a servo-driven UTM testing machine. The temperature range of the test is from room temperature to 500 °C in increments of 100 °C and strain rates of 0.01, 0.05 and 0.1 s^{-1}. The specimen temperature was controlled with a copper wire insert in the specimen. After the compression test, the specimens were immediately water quen ched and the deformed specimens subjected to micro-structural testing.

IV. EXPERIMENTAL DATA

Load and displacement values for a given strain rate and temperature were observed from computer output and sample data was collected for a strain rate range of 0.01 s -1 to 1 s -1 over temperature ranges of 100°C to 500°C. The load-displacement curve is constructed to give a displacement value on the . True stress and true strain values were calculated for different strain rates and temperatures.

V. RESULTS AND DISCUSSION

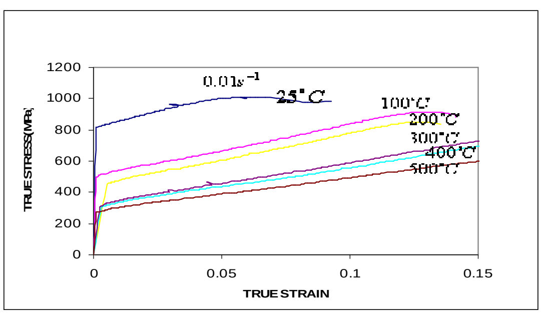

Fig.1 The stress strain curve of the titanium for different temperatures at a constant strain rate $0.01s^{-1}$

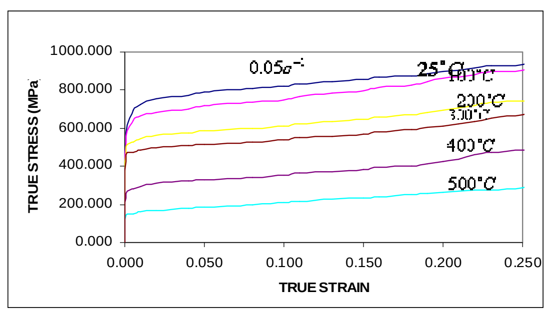

Fig.2 The stress strain curve of the titanium for different temperatures at a constant strain rate $0.05s^{-1}$

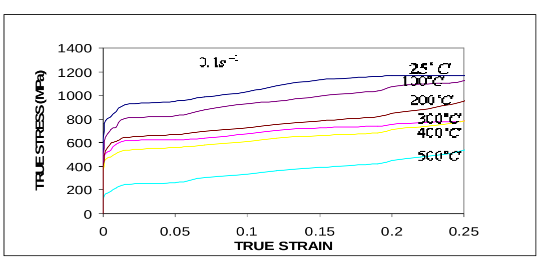

Fig.3 The stress strain curve of the titanium for different temperatures at a constant strain rate $0.1s^{-1}$

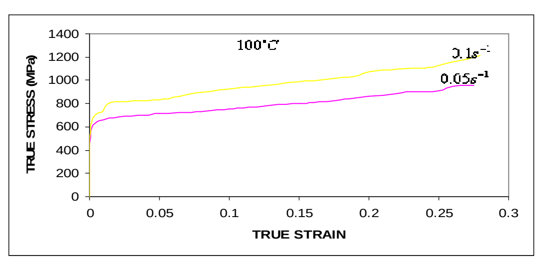

Fig.4 The stress strain curve of the titanium for different strain rate at a constant temperatures 100°C

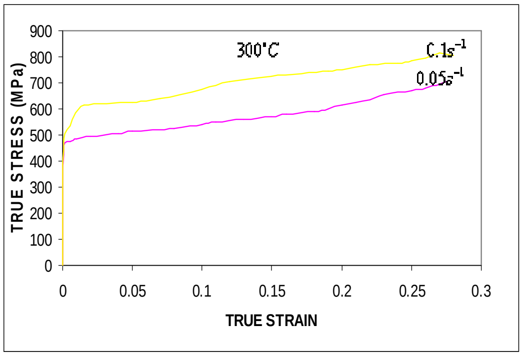

Fig.5 The stress strain curve of the titanium for different strain rate at a constant temperatures 300°C

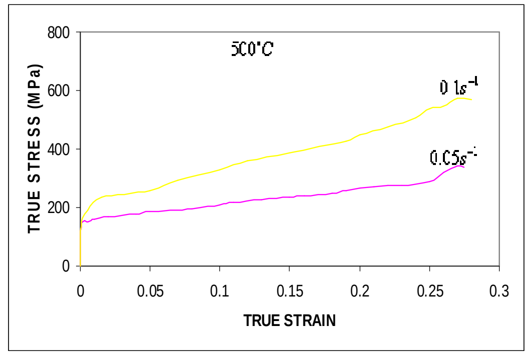

Fig.6 The stress strain curve of the titanium for different strain rate at a constant temperatures 500°C

The flow curves of the deformation process of the titanium alloy in the hot compression test at temperatures of 100 °C, 300 ° C and 500 °C and at strain rates in the range of 0.01 s^{-1}.0, 05 s-1 and 1.0 s^{-1} are in Figures 1 and 2, 3, 4, 5 and Figure 6 sho w experimentally that the flow stress increases to a peak value of 1000 MPa and then decreases, which is repressentative of flo w softening having occurred. As these numbers show that regardless of strain rate, yield strength values decrease with increasing t emperature relative to the given strain

.It is also experimental that the yield strength value increases with deformation. In addition, it was found that at low temperatures th e curing is stronger and with increasing temperature the curing decreases.

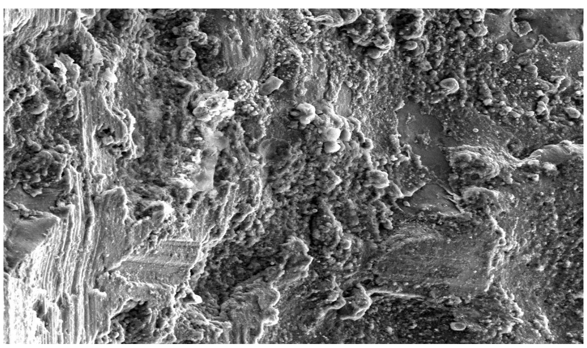

Fig 7. Globularization micro structure in the titanium specimen deformed at 100°C and strain rate 0.05s^{-1}

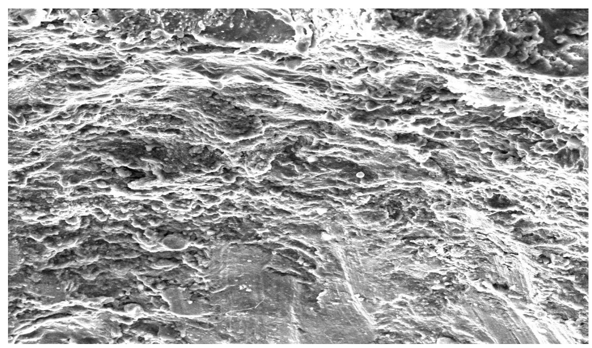

Fig 8. Bright field microstructure in the titanium specimen deformed alloy at 200°C and strain rate 0.05s^{-1}

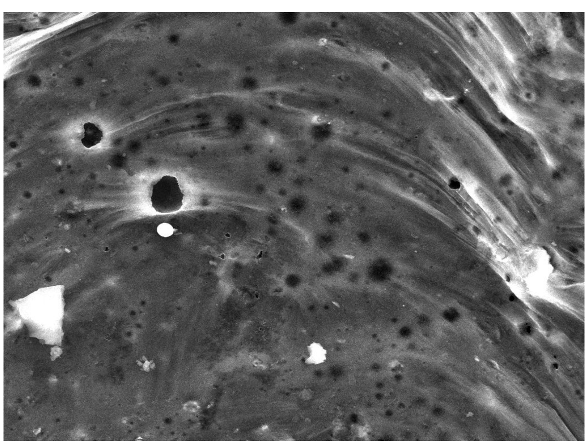

Fig.9 Dynamic recovery micro structure deformed at 300°C and strain rate 0.05s^{-1}

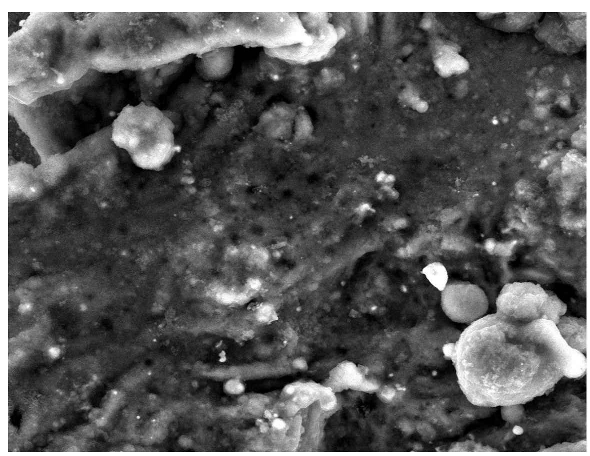

Fig 10. Dark field microstructure in the titanium alloy at 500°C and strain rate 0.1s^{-1}

They show a crystalline microstructure and a globulization of the colony structure. Outflow craters of different diameters form on the treated surface. The SEM observation of the worn micro-crack surface with normalized sliding is shown in Fig.8. The heat generated in the deformation is not dissipated due to insufficient time, reducing the stress on the nearby flow and leading to localization of the flow. The machined surface formed irregular geographies and defects, as well as debris globules and spherical particles. Due to the shear stress, a micro-crack formed at the grain boundary, which spread over several titanium compounds. When the crack finally reaches the surface, the wear debris is removed by multiple grits.Fig.9. SEM observation of thermal shock induced cracking of the worn sliding surface at the normalized value shown in Fig. 10.

VI. CONCLUSIONS

1) Behavior of titanium alloy (Ti-6Al-4V) during hot compression test at different temperatures and strain rates
2) The flow curves were developed in the strain rate range of 0.01 s^{-1} to 1.0 s^{-1} and in the temperature range of 25 °C to 500 °C.
3) A microstructure analysis was also performed and the results reported.
4) The results of the analysis were supported by an explanation of the deformation behavior of the titanium alloy.

VII. ACKNOWLEDGEMENT

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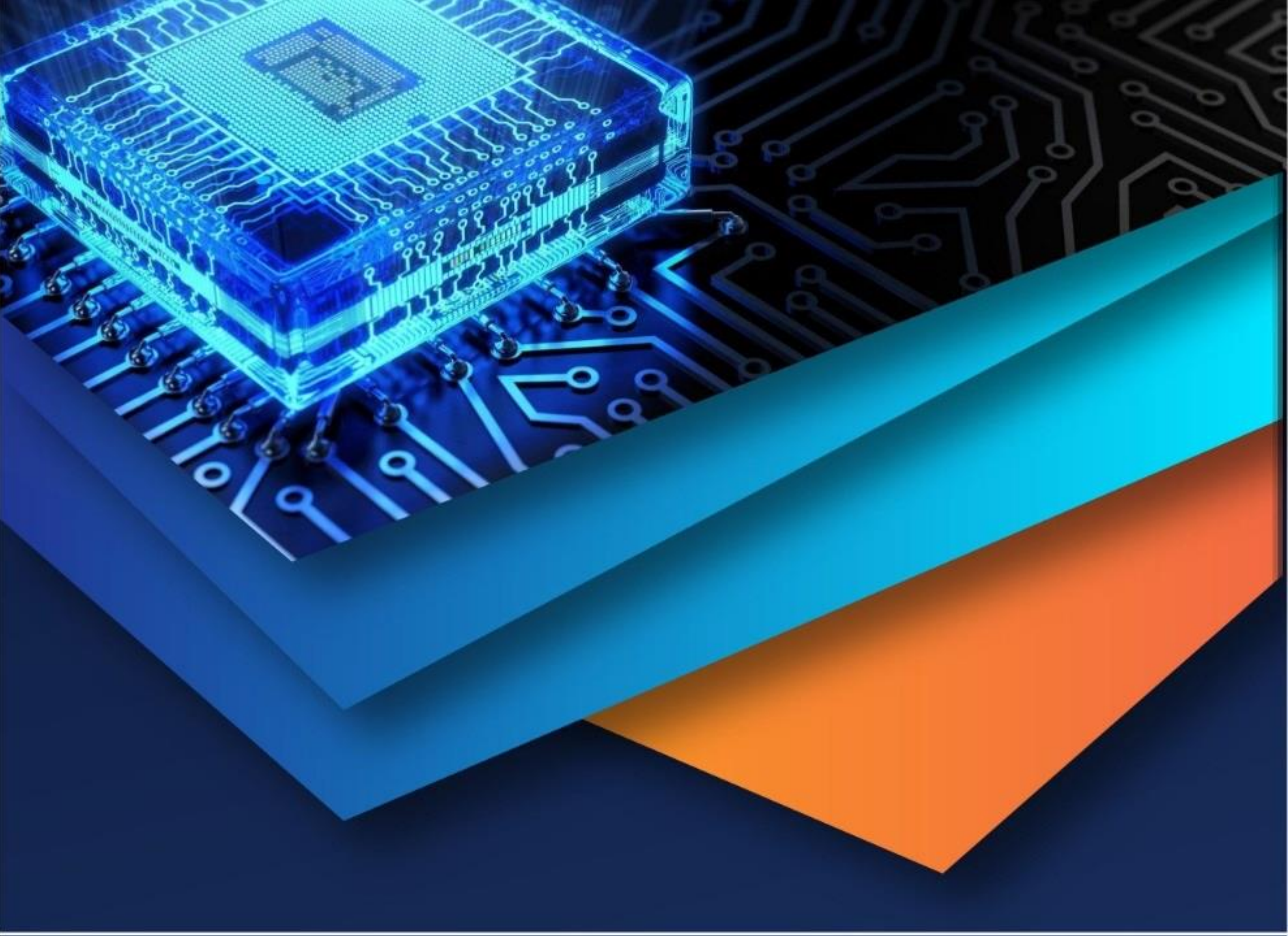
REFERENCES

[1] Jurairat Boonruab , Netraya Nimpitakpong and Watchara Damjuti, “The Distinction of Hot Herbal Compress, Hot Compress, and Topical Diclofenac as Myofascial Pain Syndrome Treatment” Volume 23, pp- 235-246, 2018
[2] Mirzadeh, Hamed; Najafizadeh, Abbas; Moazeny and Mohammad” Metallurgical and Materials Transactions , 40(12), pp-2950-2958,2009.
[3] Yue, Xian-hua, Liu, Chun-fang , Liu, Hui-hua, Xiao, Su-fen , Tang, Zheng-hua , Tang and Tian, “Effects of hot compression deformation temperature on the microstructure and properties of Al-Zr-La alloys” International Journal of Minerals, Metallurgy and Materials, 25(2), pp-243-252, 2018.
[4] Qian Qiu, Kelu Wang, Xin Li, Jun Wang, Xin Gao and Kaiming Zhang, “Hot deformation behaviour and processing parameters optimization of SP700 titanium alloy”, Journal of Materials Research and Technology, Vol.15, pp. 3078-3087, 2021.
[5] Bruschi.S, Poggio.S, Quadrini.F and Tata.M.E. Workability of Ti-6Al-4V alloy at high temperatures and strain rates, Journal of Material Science Letters , Volume 58,pp:3622-3629, 2014.,
[6] Fengyong Wu, Wenchen xu, Xueze Jin and Xunmao Zhong, “Study on Hot Deformation Behavior and Microstructure Evolution of Ti55 High-Temperature Titanium Alloy” Metals - Open Access Metallurgy Journal, Vol.7, pp. 984-993, 2017.
[7] Li.L.X, Rao.K.P, Lou.Y and Peng.D.S. A study on hot extrusion of Ti-6Al-4V using simulation and experiments, International Journal of Mechanical Science, Volume- 44, pp- 2415-2425, 2012.
[8] Prasad.Y.V.R.K, Seshacharyulu.T, Medeiros. S.C and Frazier.W.G. Influence of oxygen content on the forging response of equiaxed preform of Ti-6Al-4V commercial vs ELI grade, Journal of Materials Processing Technology, Volume- 108, pp-320-327, 2011.
[9] Seshacharyulu.T, Medeiros.S.C, Frazier.W.G and Prasad.Y.V.R.K. Microstructural mechanisms during hot working of commercial grade Ti–6Al–4V with lamellar starting structure, Materials Science and Engineering A325,pp- 112–125, 2012.
[10] Wenhua Yang, Wei Ji, Zhaohui Zhou, Aiguo Hao, Linxin Qing, Hualei Hao and Jianwei Xu, “Analysis of Deformation Behavior and Microstructure Changes for α/β Titanium Alloy at Elevated Temperature”, Temperature. Metals, Vol.11, pp. 869-876, 2021.
[11] Fengyong Wu, Wenchen xu, Xueze Jin and Xunmao Zhong, “Study on Hot Deformation Behavior and Microstructure Evolution of Ti55 High-Temperature Titanium Alloy” Metals - Open Access Metallurgy Journal, Vol.7, pp-984-993, 2017.
[12] Danying Zhou, Hua Gao, Yanhua Guo, Ying Wang, Yuecheng Dong, Zhenhua Dan and Hui Chang, “High-Temperature Deformation Behavior and Microstructural Characterization of Ti-35421 Titanium Alloy”,Materials, Vol.13, pp.1-8, 2020.
[13] Pengfei Gao, Mingwang Fu, Mei Zhan, Zhenni Lei and Yanxi Li,“Deformation behavior and microstructure evolution of titanium alloys with lamellar microstructure in hot working process”, Journal of Materials Science & Technology, Vol. 39, pp.56–73, 2020.
[14] Sheng-Di Sun, Ying-Ying Zong, De-Bin Shan, Bin Guo, “Hot deformation behavior and microstructure evolution of TC4 titanium alloy”, Transactions of Nonferrous Metals Society of China”, Vol. 20, PP. 138-147, 2010.



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