# Organic Polymer Material Research

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**ARTICLE**

# Investigation of Wooden Beam Behaviors Reinforced with Fiber Reinforced Polymers

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| ARTICLE INFO | ABSTRACT |
|---|---|

Wood material can be demolished over time due to different environmental factors. Structural elements may need to be strengthened over time as a result of possible natural disasters or during use. Beams are elements under load in the direction perpendicular to their axes. Therefore, they are basically under the effect of bending. When the studies on the behavior of beams against bending test are examined, it is known that the bottom surface of the material generally breaks. For this reason, fiber reinforced polymers (FRP) materials have been used in recent years to reinforce beam members. It is a scientific fact that it is necessary to prefer FRPs for the solution of this problem, as well as their properties such as lightness, corrosion and flexibility, their application without disrupting the appearance of wood. In this study, it was aimed to investigate the effect of reinforcing wooden beams with fiber reinforced polymer materials with different properties on different bending behaviors such as load bearing capacity, ductility, modulus of elasticity. It was observed that the ductility and bearing capacity of wooden beams reinforced with fiber reinforced polymer materials increased significantly compared to non-reinforced beams.

## 1. Introduction

Many of the historical buildings in our country and in the world consist of wooden elements. Sustaining and renewing our historical heritage requires economic power. Therefore, it is important to investigate the different strengthening methods used for repair and strengthening of historical wooden structures [1,2].

Composite materials generally consist of the main structure and reinforcing element, the main structure is called the matrix. Generally, the reinforcing material is made of fibers; carbon, glass or aramid, matrix material consists of epoxy resin [3]. Although extensive research has been done on the application of FRP composites for reinforcement, repair and reinforcement in concrete and masonry structural elements, there are limited number of studies on their application in wooden structures. The majority of current studies are focused on strengthening against bending [4-20]. Reinforcement with fiber reinforced polymers (FRP) is among the methods commonly used to repair existing wooden structures or to create high-performance structures in newly constructed wooden structures [21]. In the reinforcement process with these composite materials, various materials such as lining and glue are used during the application of fabric, sheets and rots to the wood material. Reinforcement techniques with fabric,

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sheets and rots are used to increase the strength of the timber [22] and strengthen the existing wooden structure [22,23]. Studies have been done especially on both solid wood [22-25] and glulam materials. Flexural behaviour of glulam timber beams reinforced with FRP cords.

In traditional reinforcement techniques, it is generally recommended to use metal in wooden structures. However, considering the superior aspects of FRP to be used compared to metals, the most important advantages of FRP strips compared to steel strips are; lightness, corrosion and flexibility can be listed. It is inevitable that reinforcements made with steel need maintenance over time, create visual pollution in the reinforced areas and bring extra load to the structure. It is a scientific fact that fiber reinforced polymers, as well as their properties such as lightness, corrosion and flexibility, can be applied without disturbing the appearance of wood, and that FRPs should be preferred in the solution of this problem [3].

In this study, it was aimed to investigate the effect of reinforcing wooden beams with fiber reinforced polymer materials with different properties on different bending behaviors such as load bearing capacity, ductility, and modulus of elasticity.

## 2. Fiber Reinforced Polymer Composite Materials

Composite materials can be briefly defined as "materials formed by the combination of two or more components that are macro-different from one another across an interface". The components that make up the composite material mostly retain their properties [26]. Understand the behavior of a composite material; it is necessary to know the functions of the fibers and matrix materials in the composite material (Figure 1) [27]. The important duties of fiber fibers and matrix materials can be listed as follows [28].
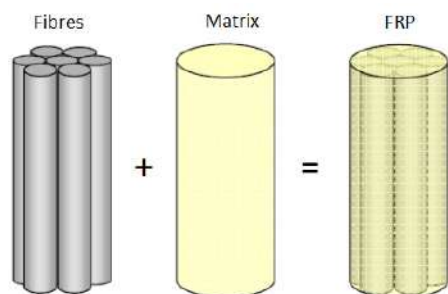


**Figure 1.** Constituents of Fiber Reinforced Polymers Materials [27]

## 3. Production and Properties of Fibers

Materials such as glass, carbon and aramid, which are melted at high temperatures, are flowed down by a thin (capillary) perforated tank, and they are suddenly cooled by spraying water on them, and are rapidly drawn by stretching with continuously rotating rollers, and this stretch process produces micron-level fibers. In order for these fibers to have a good adherence with resins, surface improving materials (such as Silane) are coated on them [29]. These stages are shown schematically in Figure 2.
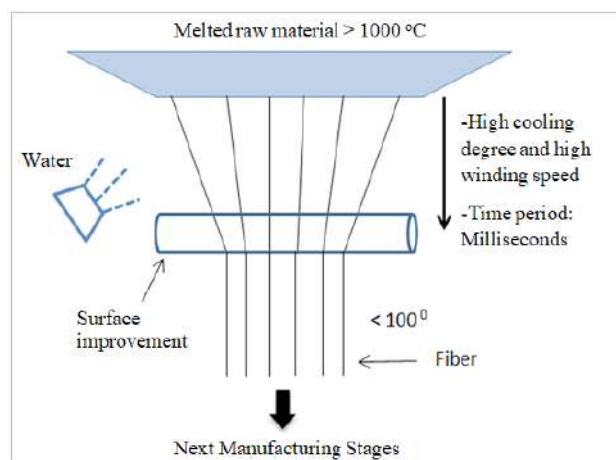


**Figure 2.** Production stages of fibers

As seen in Table l, the elasticity module and the highest tensile strength are carbon fibers. PVA fibers are the most likely to have elongation at break.

**Table 1.** Range of change of mechanical properties of fibers [30]

| Properties | Fiber Types | | | |
| --- | --- | --- | --- | --- |
| | Carbon | Aramide | PVA | Glass |
| **Modulus of Elasticity (GPa)** | 290-400 | 62-142 | 8-28 | 72-78 |
| **Tensile Strength (MPa)** | 2400-5700 | 2410-3150 | 870-1350 | 3300-4500 |
| **Breaking Elongation (%)** | 0,3-1,8 | 1,5-4,4 | 9,0-17,0 | 4,8-5,0 |

Figure 3 shows the stress-strain curves of the fibers used for reinforcement.
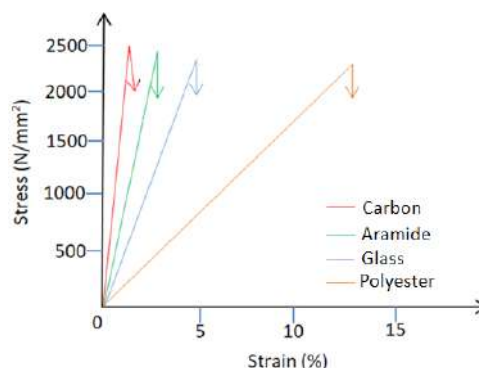


**Figure 3.** Stress-strain curve of fibers

As seen in this diagram, while the stress-deformation diagram of carbon, aramid and glass (E-glass) fibers are close to each other, deviation is higher in polyester fibers.

## 4. Use of Fiber Reinforced Polymers in Strengthening Wooden Beams

Nowadays, most of the historical wooden houses have been demolished and many have been damaged. This has led to the need for a safe and fast repair of our existing wooden structures. Classical restoration techniques can be developed in terms of preserving historical texture, time, cost and security. It is of great importance to repair the bearing elements of wooden structures with FRP in a very short time in terms of safety and time and visuality.

Plevris and Triantafillou [31] made comparisons between the analytical model and experimental studies they developed to estimate the creep behavior of CFRP reinforced wooden beams in their work titled "Creep behavior of FRP reinforced wooden building elements" and reported that they are compatible with the analytical model. Ogawa [32] made reinforcements and compared their bending strengths by bonding carbon fiber reinforced fiber strip to various regions of laminated wooden beams or by wrapping the entire beam with carbon fiber at certain intervals. It also observed the behavior of reinforced samples under temperature and detected a 300% performance increase. Premrov et al. [33] examined the analysis of wooden structural elements reinforced with carbon fiber reinforced polymers. With the reinforcement of wooden building elements with 75 mm CFRP, they achieved a 50% higher strength. Steiger [34] conducted studies on the bonding of high performance carbon fiber reinforced polymers to wood with epoxy in wood structures and the effect of epoxy on tensile strength. It has determined the best reinforcement properties at optimum temperature. Author reported that the optimum values of the adhesion temperature of the epoxy resin with CFRP to the wood are in line with the values given by the glue manufacturers. Roberto et al. [35] conducted a study on structural classification of completely damaged wooden columns reinforced with FRP composite boards. In the data obtained as a result of bending tests, a 60% improvement was found with FRP composite plates. Borri et al. [5], in their study on the behavior of wooden structural elements reinforced with CFRP under loads, compared the non-linear models of existing wooden structural elements with the estimated load amount.

In the past two decades, research has been done on the structural application of wood-based composites. The performance of glulam timber columns reinforced with FRP (Fiber Reinforced polymer) sheets was investigated by Taheri et al. [36]. Experimental results and computational modeling have shown that stiffness and resistance can be significantly improved with FRP. O'Loinsigh et al. [37] conducted experimental and numerical research on wooden dowels and multi-layer wooden beams, demonstrating that a desired bending stiffness can be achieved with a reasonable combination of material and geometric parameters. Chans et al. [38] examined the axial resistance of the connections made with steel rods glued to the joints of the wood material. Although there are many experimental studies on the joints of glued laminated timber (glulam), they emphasized that the experimental data on the joints tests are still limited.

Although extensive researches have been made on the application of FRP composites for reinforcement, repair and reinforcement in concrete and masonry structural elements, there are limited studies on their application in wooden structures. The majority of current studies are focused on strengthening against bending [4-20]. In addition, regional reinforcement studies have been carried out to increase shear strength perpendicular to the fibers [23,39,40] and perpendicular to the fibers [41]. Successful application of FRP reinforcement to wooden elements requires the establishment of a high quality and durable bond between two different materials. Various studies have also been carried out to investigate this aspect of strengthening with FRP [42-47].

Lindyberg [48] stated that various design methods are used to analyze reinforced and non-reinforced beams in bending. These methods can be divided into empirical, deterministic and probabilistic. ASTM D 3737/96 - (Standard Test Method for Building Stresses) creates empirical methods for the design of beams produced from structural glued laminated timber (Glulam). These methods take into account the bending strength of error-free test samples and create modification coefficients for existing defects in these elements. The author concluded that reinforced glulam beams have a complex tearing mode that makes it difficult to use experimental solutions. Lindyberg [48] presented a semi-probability calculation model to calculate the strength and stiffness of reinforced glulam beams. Author stated that the model is the most effective solution to evaluate the resistance and hardness of the material. The calculation procedure consists of two stages. The first part consists of a deterministic numerical model that calculates the load-bending curve of the reinforced beam. This model is based on the moment of curvature (M-φ). The second part includes the deterministic model in a probabilistic model. The Monte Carlo computational simulator was used to devel-

op the probability model in the deterministic model.

Fiorelli and Dias [8] provided a decisive model for calculating the stiffness and resistance of fiber-reinforced timber beams. To calculate the rupture mode, the model takes into account tearing by compression of the upper fibers or stretching the lower fibers. To evaluate the final moment, the model takes into account the final tensile and compressive strength of the timber. This model is based on the Navier / Bernoulli hypothesis. If the comparison of experimental and theoretical results is made, they determined that both experimental and theoretical results give very similar strength and hardness values. Romani and Blab [49] presented a design model for fiber-reinforced glulam beams. In this study, the authors showed different breaking modules for reinforced glulam beam.

Raftery and Harte [50] produced layered laminated beams produced by gluing spruce beams on top of each other. In reinforced beams, FRP plates are placed between the beams. Reinforced and non-reinforced beams were subjected to bending test. They examined the load-displacement behavior, stiffness and final moment capacity of beams. They also developed a finite element model with nonlinear material modeling and nonlinear geometry to estimate these properties.

Li et al. [51], examined the bending behavior of wooden beams reinforced with Glass Fiber Reinforced Plastic (GFRP) rod and Carbon Fiber Reinforced Plastic (CFRP) composite boards. In the study, he examined the load-displacement behavior of beams under bending effect. A cross-sectional analysis method is proposed to obtain the relationship between force-displacement of these wooden beams reinforced with GFRP rod and CFRP boards. Analytical results have been shown to reasonably predict the force-displacement relationships of these wooden beams reinforced with the GFRP rod and CFRP boards.

Xiong et al. [52] aimed to discuss the applicability of reinforcement, to evaluate the contributions of different methods and to examine the seismic performance of samples. They used Canadian spruce-pine-fir (SPF) glulam in their studies. They are wrapped with 0.11 mm thick CFRP. All the samples used had a span of 4,110 mm and a height of 2,740 mm. The column sections used in the study are 280 mm x 230 mm; beam sections are 280 mm x 180 mm and support sections are 135 mm x 105 mm. Monotonic and cyclic tests were performed using a hydraulic actuator at Tongji University. They used a hydraulic actuator with a displacement distance of ± 250 mm and a capacity of 650 kN. As a result of the study, they determined that all samples of the reinforced series regain their load bearing capacity. While the screws used provide a pre-stretching effect, wrapped FRP materials have been determined to tend to limit cracks passively.

Wang et al. [53] summarizes a series of experimental and numerical study results on the mechanical behavior of such connections (bolted glulam column-beam) under various combinations of shear force and bending moment defined by shear-moment ratio λ. Based on the samples tested in this study, they found that the moment resistance in the junction area increased by 31.6% of the pure moment resistance, as the shear-bending ratio (λ) increased. In the meantime, they determined that the shear-bending ratio (λ) decreased and the pure shear resistance decreased by approximately 46.1%. The FEM model developed based on the elastic-plastic damage forming the wood and wood foundation model and the test results obtained were determined to give parallel results (16.7% and 11.1% modeling error for bending moment and shear resistance respectively). They stated that the interaction for a small shear-moment ratio (λ <1.53) can be expressed by a quadratic function, a linear function would be more appropriate for the large shear-moment ratio (≥0.53).

Kılınçarslan and Şimşek Türker [54] examined the effect of strengthening the wooden beam with FRP fabric on the load bearing capacity and elasticity modulus values of the material. They determined that the final displacement was less in the wooden beams reinforced with FRP fabric and there was an increase in ductility and bearing capacity.

## 5. Conclusions

Besides the many positive properties of the wood material, it also has negative properties. Therefore, the natural strength of the wood material; In other words, changes in durability characteristics can be seen against different environmental factors in the field of use. One of the methods used to increase the resistance properties of wood material is reinforcement with fiber reinforced polymers. In this study, studies that reinforcing wooden beams with fiber reinforced polymers increase the load bearing capacity of beams are researched and it's presented.

Application of fiber reinforced polymers is a solution method that can be used to strengthen wooden systems in cases where load bearing capacity and stiffness are required to be high. In addition, the absence of an abrasive material offers the possibility of reducing long-term maintenance costs and rapid application on the job site. Fiber-reinforced polymers can be applied not only to strengthening the carrier elements while building the structure, but also to the damaged sections of columns and beams as restoration work in wooden houses of historical value and can help increase the resistance of these houses against external influences for a long time. It is important

to expand the use of FRPs in terms of protection, strengthening and sustainability of historical wooden structures.

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**ARTICLE**

# A New Study on the Superplasticity of TiAl Alloys

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| ARTICLE INFO | ABSTRACT |
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| | The superplasticity of Ti-46.7Al-2.2Cr(at.%) alloy was studied by mathematical induction. It is found that Zener Hollomon relative formula and there are serious deflections. According to the true superplastic stress and true strain curves, the deflection values of n=-7.46 and B=1439MPa are obtained, indicating that the limit of n>0 has been exceeded, which needs to be characterized by a negative sign. This shows that it conforms to the principle that the smaller n is, the better superplasticity is, but the problem that it has become a negative number needs to attract the attention of peers meantime B is a better match. |

## 1. Introduction

Superplasticity is a significant phenomenon in TiAl. The n and B is usually determined with Zener Hollomon formula. [1] 0<n<1 is the scope of n. But it can not be represented according to formula. So in this paper it is investigated that the n and B in terms of Boyun Huang et al [2] experiment on TiAl superplasticity behavior. It is calculated that n and B is from the modeling which is adopted with their experimental data. n and B will become small when the superplasticity is taken according to new finding [3]. But n is small and B is normal which is acquired in this paper. So n is fitting to finding. Because the n and B is important in superplasticity research due to its true stress and true strain relationship. Not only from experimental value but also from parameters can we control and utilize it. So that these parameters feature need

to be found for us to use them practically. Only this can we finally solve our difficulties to wield superplasticity function to meet our high elongation needs. For instance to aircraft it will be applied from one hand. On the other hand to spacecraft it will be applied too due to its excellent property. It is hoped that this study satisfies to search parameters of superplasticity on Ti-33Al-3Cr(wt.%) in this paper.

## 2. Modeling

According to

$$\sigma = K\varepsilon^n \tag{1}$$

takes (1) to natrural logarithm

$$LN\sigma = LNK + nLN\varepsilon \tag{2}$$

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takes random two points coordinate

$$LN\sigma_1 = LNK + nLN\varepsilon_1 \tag{3}$$

and $LN\sigma_2 = LNK + nLN\varepsilon_2$ (4)

From above two formula it is gained

$$n = \frac{LN\left(\dfrac{\sigma_1}{\sigma_2}\right)}{LN\left(\dfrac{\varepsilon_1}{\varepsilon_2}\right)} \tag{5}$$

And

$$K = EXP\left[LN\sigma_2 - \frac{LN\left(\dfrac{\sigma_1}{\sigma_2}\right)}{LN\left(\dfrac{\varepsilon_1}{\varepsilon_2}\right)}LN\varepsilon_2\right] \tag{6}$$

Here B=K is strength coefficient; n is work hardening exponent. Two points were measured through the curve in reference that is the true stress and strain curve causing the super plastic behavior in TiAl alloys. We supposed that these two points coordinates are 1 and 2 as above.

## 3. Discussion and Conclusions

The Zener Hollomon formula and the relative formula are the series formulas. [1] the feature values of n=-7.46 and B=1439MPa are obtained by taking points from the experiment [2] and calculating the above model, indicating that the limit of n>0 has been exceeded, which needs to be characterized by a negative sign. This shows that it conforms to the principle that the smaller n is, the better superplasticity is, but the problem that it has become a negative number needs to attract the attention of the material research colleagues. Here 0<n<1 is the normal value, and the negative value of n indicates that it has exceeded the calculation limit and is a negative partial value. What that means is that when n goes down to zero and then goes down to minus 7 that's the superplasticity value. It indicates that the superplasticity has exceeded the limit capacity, and only the negative value is its choice, and the greater the negative value indicates that the greater the superplasticity value and the better the superplasticity. Here the strain is selected as 1.85, while the stress is 29MPa. This is n at this fracture value. B is 1439 which is a little bit larger. It is not clear why B value is too high, but B value is reasonable.It is found that B value is inferior to n value in superplastic deformation. According to Boyun Huang et al., the temperature was 1025 ℃ and the strain rate was $2 \times 10^{-4}$ / s. The fine grain diameter of the experimental structure was 2-3μm and the composition was Ti-46.7%Al-2.2%Cr (atomic fraction). As shown in Table 1 the parameters is listed for instance $\sigma_1, \varepsilon_1$ and $\sigma_2, \varepsilon_2$ to calculate the parameters n and K according to Modeling above. Although it has little value when the plasticity becomes big according to the reference research it may be had some reason. For example if superplasicity happens it may follow its intrinsic feature as for these two parameters. As for B according to other reference there is some normal value in the same to superplasticity in $Ti_3Al$ alloys which directional tensile strain reaches about 300%. So it is supposed that the phenomenon of normal B is affected by its intrinsic substance. It shall be further researched to investigate in detail. If B behavior is investigated detail the intrinsic feature will be cleared and clarified in the end.

**Table 1.** The parameters n and K with $\sigma_1, \varepsilon_1$ and $\sigma_2, \varepsilon_2$ in TiAl

| Items | $\varepsilon_1$ | $\varepsilon_2$ | $\sigma_1$ | $\sigma_2$ | n | K/MPa |
|-------|------|------|------|------|-------|-------|
| value | 1.85 | 1.47 | 29 | 77 | -7.46 | 1439 |

Now we take a way to calculate the atomic fraction as mentioned above on mass fraction of Ti-33Al-3Cr. It is Supposed that:

Ti-XAl-YCr is in atomic fraction. X is Al and Y is Cr atomic fraction respectively. So Ti fraction is 100-X-Y. Accordin to atomic fraction equivalence it has:

$$\frac{33/27}{64/48} = \frac{X}{100-X-Y} \tag{7}$$

and

$$\frac{3/52}{33/27} = \frac{X}{Y} \tag{8}$$

From (8) it is gained that

$Y=0.047X$ (9)

To substitute (9) into (7), it gains

$X=46.7$ (10)

To replace (7) or (8) with (10), we gain

$Y=2.2.$ (11)

So the final content of this alloy is Ti-46.7Al-2.2Cr(at.%).

Here atomic weight Ti=48, Al=27, Cr=52.

## 4. Conclusions

In the superplasticity experiment, when the fracture strain

is 1.85 and fracture stress is 29MPa, n is -7.36, and the negative value indicates that n is the inverse value, that is, the minimum value. The superplasticity has exceeded the limit capacity, and the great negative value indicates that the greate superplasticity value. B is a relatively normal value of 1439MPa, which is a certain high value for Ti-33Al-3Cr(wt.%) alloys. It is supposed that B is normal generally and affected by its intrinsic substance.

## Foundation

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**ARTICLE**

# Study on Microstructure and Properties of Pure Ti flat Wire

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ABSTRACT

The titanium round wires could be prepared to the high precision flat wires with the sizes of 0.63mm×5.03mm by nine-pass cold continuous rolling process.Mechanical property and metallograph analysis were used to analyze the possibilities of preparing flat wire. Results show that the grain kept equiaxed grain in the rolling processes,and a large number of dislocation and a small amount of twin existed in the microstructure of final rolling flat wire.During the whole rolling processes, when the accumulated rolling deformation degree was at low degree, the deformation of titanium was controlled under the mutual control of dislocation slip and twinning. When the accumulated rolling deformation degree was at high degree, the deformation of titanium was controlled by the dislocation slip.

## 1. Introduction

Pure titanium has good properties such as high specific strength, good biocompatibility, corrosion resistance and so on. It has a wide application prospect, and is very popular in aerospace, petrochemical and other fields. However, because the α-Ti, with hcp lattice structure at room temperature is difficult to achieve the plastic deformation of pure Ti by slip alone, it is necessary to rely on twins to assist in the deformation [1]. In unidirectional cold rolling of high purity titanium by Ruoyu Zhang [2], it is found that both slip and twin participate in deformation when the deformation is less than 50%, and the twins contribute more in the deformation process, so a large number of twins appear in the microstructure. If the amount of deformation is not less than 50%, the slip is less than 50%. The contribution of shape gradually increases and exceeds the effect of twins, and the twins in the microstructure will gradually decrease and the deformed bands will be formed at the same time. Shankun Chen [3] of Xi'an Jiaotong University found that the original equiaxed microstructure of ultra-fine grained TA1 pure titanium plate prepared by repeated rolling process was gradually elongated and evolved into fine grain. When the equivalent effect was more than 2.4, it was found that the original equiaxed structure was gradually elongated and evolved into fine grain. A large number of substructures formed by dislocation entanglement were observed in TEM images, but no twins were observed, and the dislocation motion was the main deformation mechanism.

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The cold continuous rolling process was used to flatten industrial pure titanium. The microstructure evolution and deformation mechanism of industrial pure titanium during flat rolling were studied by mechanical properties test and microstructure observation. In order to explore the stable forming process of pure titanium flat wire with high precision.

## 2. Trial

### 2.1 Test Material

The industrial pure Ti filament treated with Φ 2.5 mm was used in the experiment. The main chemical composition of the filament was shown in Table 1.

Table 1. Chemical composition of commercial pure titanium wire （wt%）

| Ingredient | Ti | Fe | C | N | H | O |
|---|---|---|---|---|---|---|
| content | allowance | 0.20 | 0.08 | 0.03 | 0.015 | 0.18 |

### 2.2 Rolling Mill Practice

Industrial pure Ti flat wire was prepared by two high and three tandem rolling mill. The rolling is divided into nine passes, and the roll diameter is 150. The rolling process is cooled and lubricated with 10 # oil, the rolling speed is 18 m / min, the pass reduction is distributed as shown in Table 2. The rolling process is divided into 9 passes, and the roll diameter is 150. The rolling speed is 18 m / min, and the rolling speed is 18 m / min.

Table 2. Reduction distribution of commercial pure titanium wire （unit：mm）

| Pass | Outgoing gauge | Pass compression ratio | Cumulative compression ratio |
|---|---|---|---|
| 1 | 1.99 | 20.40% | 20.40% |
| 2 | 1.77 | 11.06% | 29.20% |
| 3 | 1.56 | 11.86% | 37.60% |
| 4 | 1.37 | 12.18% | 45.20% |
| 5 | 1.20 | 12.41% | 52.00% |
| 6 | 1.05 | 12.50% | 58.00% |
| 7 | 0.86 | 18.10% | 65.60% |
| 8 | 0.65 | 24.42% | 74.00% |
| 9 | 0.63 | 3.080% | 74.80% |

### 2.3 Mechanical Property Test and Microstructure Observation

The tensile tests at room temperature for Φ 2.50mm pure titanium round wire and each pass flat wire were carried out on the WDW- 100 10 ton electronic drawing machine. The total length of single specimen was 160 mm, 50mm and the tensile speed was 1 mm/min. The hardness test was carried out on the Waubert 401 MVD digital display microhardness tester. The loading force was 300 gf, holding time of 10s. The hardness test was divided into two types: hardness test in the direction of flat wire rolling (longitudinal) and hardness test on its cross section. Olympus - G51 metallographic microscope for metallographic observation, corrosion agent HF3ml, HN O315ml, H2O30ml. Tem test was carried out at Xi'an Jiaotong University.

## 3. Test Results and Analysis

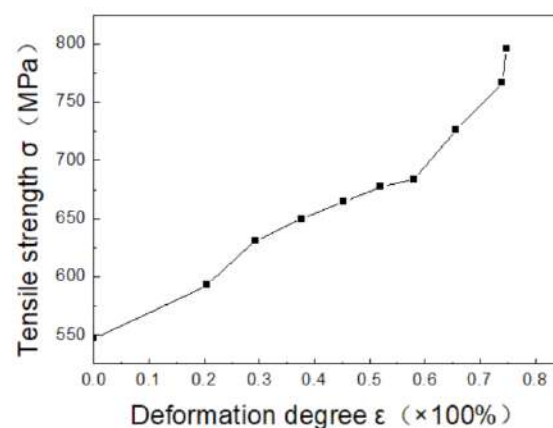### 3.1 Mechanical Properties of Flat Wire under Different Rolling Conditions



Figure 3. The relation between tensile strength and deformation of commercial pure titanium wire

As can be seen from Figure 3, the original tensile strength of industrial pure Ti wire with Φ 2.50mm size after warm drawing is 547 MPA, which is cold rolled according to technological regulations. It is found that the trend of tensile strength changes with the increase of deformation degree, and the tensile strength of titanium wire increases continuously. When the total compression ratio of the first rolling stage is 37.60%, the tensile strength of the titanium wire reaches 649.7 MPA, the tensile strength of the titanium wire reaches 796 MPA when the total compression ratio of the second rolling stage is 58.00%, and the tensile strength of the titanium wire reaches 796 MPA when the total compression ratio of the third rolling process reaches 74.8%. After three rolling periods, compared with the round wire before unrolled The increment of tensile strength of titanium wire is 102.7 MPA, 37.3MPa and

112MPa respectively. Therefore, the change rule of tensile strength of industrial pure Ti flat wire during rolling is as follows: with the increase of deformation degree, the tensile strength of Ti wire increases greatly, but the work hardening degree of the second rolling process is smaller.
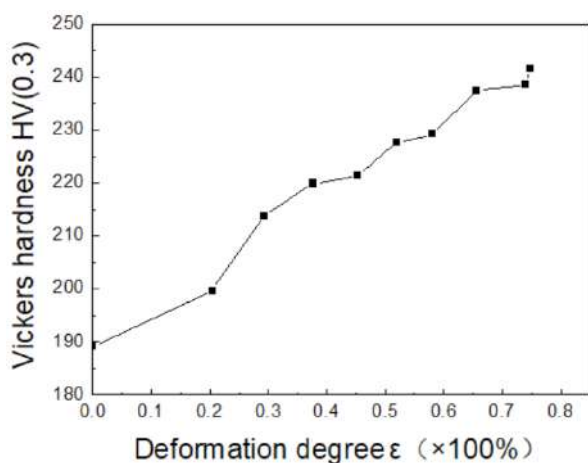


**Figure 4.** The relation between microhardness and deformation of commercial pure titanium wire

In Figure 4, the microhardness of Φ 2.50mm's industrial pure Ti filaments is 189.1HV (0.3). It is found that the change trend of microhardness is the same as that of tensile strength: with the increase of deformation degree, the change trend of microhardness is the same as that of tensile strength. The Vickers hardness of Ti filament increases continuously. When the compression ratio is 37.60%, the microhardness is 219.9HV (0.3). In the sixth pass, when the compression rate is 58.00%, the microhardness is 229.2Hv (0.3), and when rolling to the ninth pass, the total compression rate reaches 74.8%, the microhardness is 241.6HV ( 0.3). The increment of microhardness after rolling is 30.8HV (0.3), 40.1HV (0.3) and 52.5HV (0.3) respectively) compared with the round wire before rolling. Therefore, the microhardness of industrial pure Ti flat wire during rolling is as follows: with the increase of deformation degree, the microhardness increases. The hardness of industrial pure Ti flat wire is also tested. The industrial pure Ti wire is rolled to the finished product according to the rolling schedule shown in Table 2, and the total reduction rate reaches 74.8%. The hardness distribution of the hardness point on the cross section is shown in Figure 5, and the hardness distribution of the cross section is obtained. As shown in Figure 6.
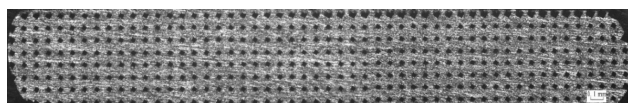


**Figure 5.** Distribution of microhardness points on cross-section of commercial pure titanium flat wire
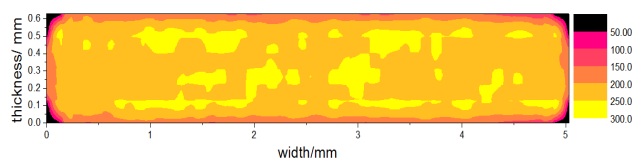


**Figure 6.** Distribution of microhardness on cross-section of commercial pure titanium flat wire

Figure 6 when the total reduction rate of industrial pure Ti flat wire reaches 74.8%, the hardness distribution of cross-section increases gradually from the edge to the cross-section center in the wide direction, and the hardness of the cross-section increases from the rolling surface to the cross-section center in the thickness direction. The maximum hardness of the core and the minimum hardness of the edge are 281.8HV (0.3) and 103.4HV (0.3), respectively. The central high hardness region is X-shaped, and X extends to the whole cross-section along the direction of extension, and the hardness of the rest tends to be uniform. This is because with the increase of deformation, the deformation zone will gradually expand to the contact area and the wide area, so that the deformation of the entire section will be more uniform.

## 3.2 Microstructure of Flat Wire under Different Rolling Conditions
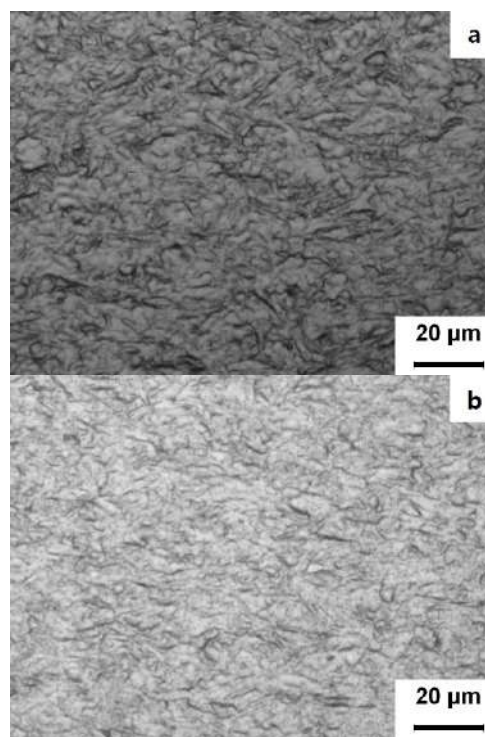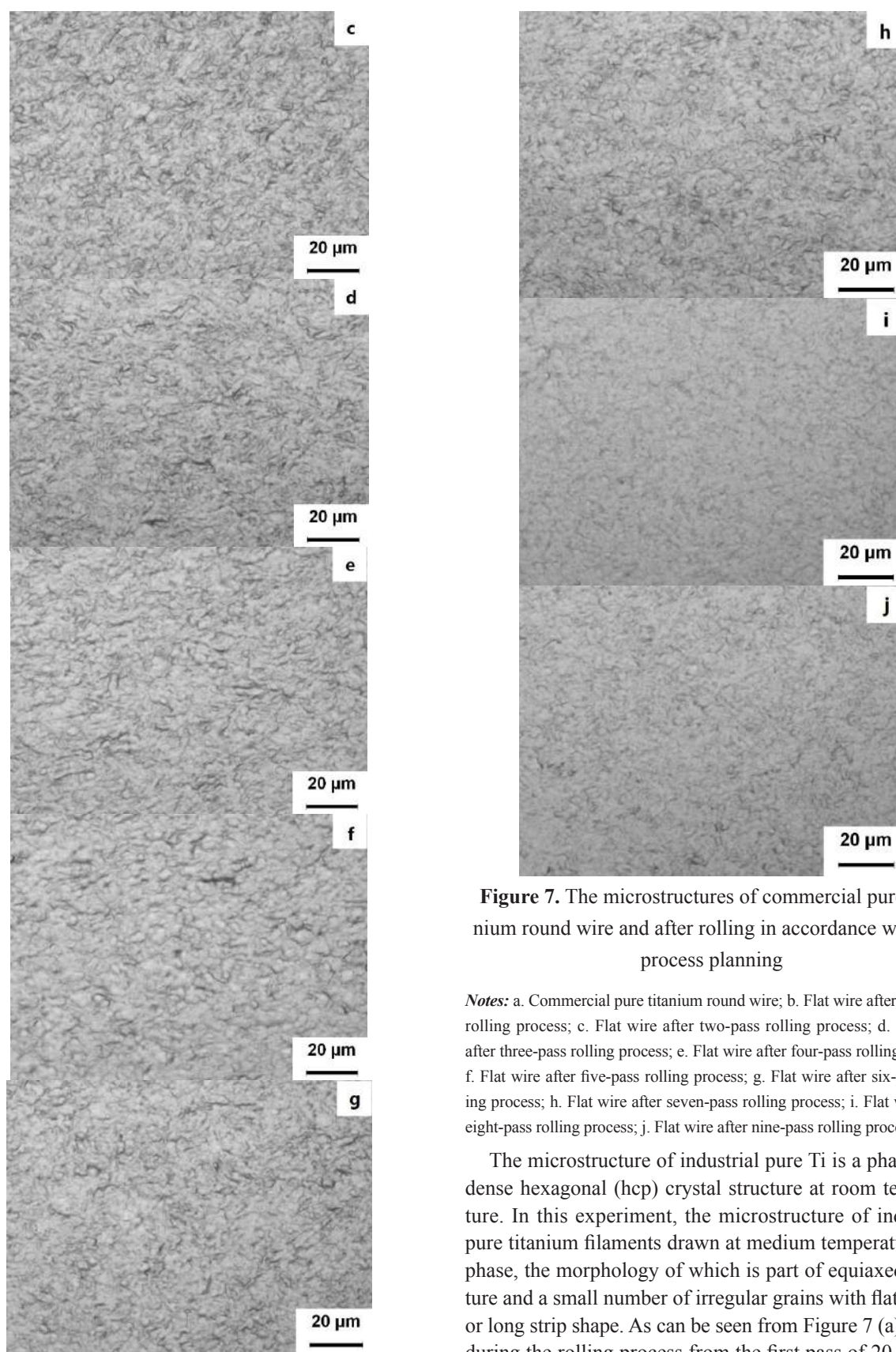
**Figure 7.** The microstructures of commercial pure titanium round wire and after rolling in accordance with the process planning

*Notes:* a. Commercial pure titanium round wire; b. Flat wire after one-pass rolling process; c. Flat wire after two-pass rolling process; d. Flat wire after three-pass rolling process; e. Flat wire after four-pass rolling process; f. Flat wire after five-pass rolling process; g. Flat wire after six-pass rolling process; h. Flat wire after seven-pass rolling process; i. Flat wire after eight-pass rolling process; j. Flat wire after nine-pass rolling process.

The microstructure of industrial pure Ti is a phase with dense hexagonal (hcp) crystal structure at room temperature. In this experiment, the microstructure of industrial pure titanium filaments drawn at medium temperature is α phase, the morphology of which is part of equiaxed structure and a small number of irregular grains with flat ellipse or long strip shape. As can be seen from Figure 7 (a) - 7 (j), during the rolling process from the first pass of 20.40% to the final cumulative reduction rate of 74.80%, the basic

shape of grain does not change, and most of the grains are equiaxed. Only with the increasing of the reduction rate, the equiaxed structure is more refined and the original grain boundary is blurred. This indicates that in rolling plastic deformation, intra and intergranular deformation occurs. The deformation mechanism plays an important role. This is because slip is not easy to occur during plastic deformation of hcp crystal. In the initial rolling stage, only a small number of grains with favorable orientation will slip, and there will be interaction between adjacent grain boundaries and shear stress at the grain boundary. When the shear stress increases to overcome the resistance of grain sliding to each other, the grain boundary will slip. For the grains in the unfavourable orientation, the intergranular interaction will gradually turn to the orientation conducive to slip. Neither of the above two intergranular deformation modes can change the original morphology of the grain and promote the intra-crystal deformation. That is, when there are more crystals, When the grain is in a favorable slip direction, the slip and twin-dominated intra-crystal deformation will play a major role. In Figure 7, the grain refinement of the final rolling structure is related to the slip and the twinning of the grain refinement in the (j). This also explains the reason for the increasing tensile strength and hardness in Figure 1 and Figure 2, that is, fine grain strengthening.

Dislocations and twins in α-Ti microstructure have great influence on plastic deformation, but these structures are not visible under OM. In order to find out the change of microstructure in pure Ti deformation, the TEM analysis of the flat wire rolled to the ninth pass is carried out as follows.

Figure 8 (a) - 8 (g) are all TEM photographs of flat wire after the ninth pass cold rolling. As can be seen from Figure 8 (a), there are a large number of high density dislocations along the grain boundary in the α-Ti, microstructure with single phase after rolling, a large number of dislocation cells formed by dislocation entanglement and a small number of subcrystalline structures in some regions of the grain boundary. According to the (b) diffraction speckle in Figure 8, there are nanocrystalline grains formed after the grains are broken and the diffraction spots are circular, indicating that there is internal stress in the microstructure and the lattice is distorted and deformed violently. Figure 8 (c) is a local area of the same organization in which both dimensions are found The dislocations are concentrated in the equiaxed grains and entangled. In the large grain regions, there are already formed dislocation cells, and the dislocations are concentrated on the cell walls to form dislocation walls, and the dislocations are concentrated on the cell walls, and in the large grain regions, the dis-

locations are mainly distributed on the cell walls, and the dislocations are concentrated on the cell walls to form dislocation walls. However, there are very few intra-cellular dislocations. Figure 8 (d) shows dislocation cells formed by a large number of dislocation entanglement in the microstructure, which indicates that dislocation slip plays an important role in cold rolling plastic deformation of pure Ti, and as can be seen from figure (a), (c), (d). After cold rolling, the microstructure of industrial pure Ti is not uniform, and its inhomogeneity is reflected in grain size and sub-structure distribution. Figure 8 is more visible in the organization as shown in (e) The results show that the dislocation in the inner part of the cell wall is attracted to the dislocation wall of the cell wall and rearrangement and cancellation occur, the dislocation in the central region decreases, the orientation difference of the grain boundary increases, and a large angle grain boundary is formed, which indicates that the dislocation of the inner part is attracted to the dislocation wall of the cell wall in the process of deformation. The organization was refined. Although the plastic deformation modes of pure Ti are slip and twinning, there are very few twinning structures under the condition of large deformation with a total reduction rate of 78.40%. As shown in Figure 8 (f), the twins are fine needle-like with a large number of dislocations distributed on both sides. Figure 8 the twinning staggered motion in (g) causes the grain to be segmented so that the grain can be refined and a large number of fine equiaxed crystals can be obtained.
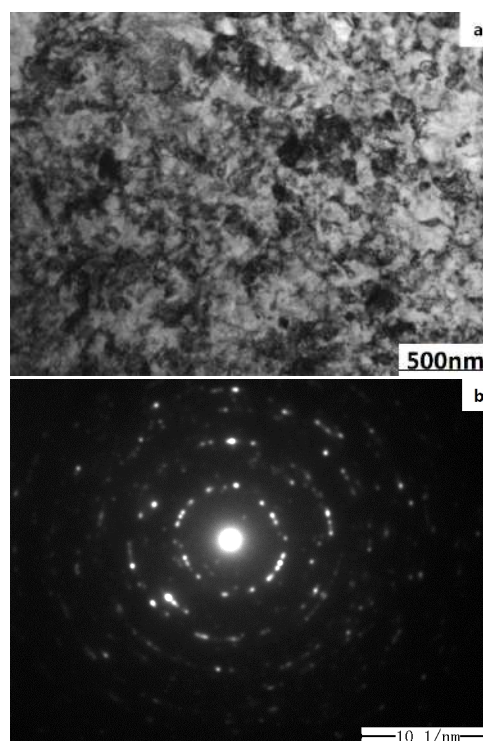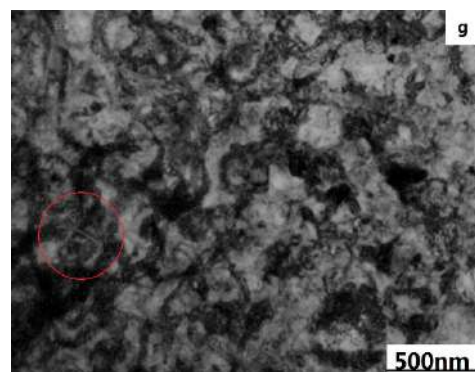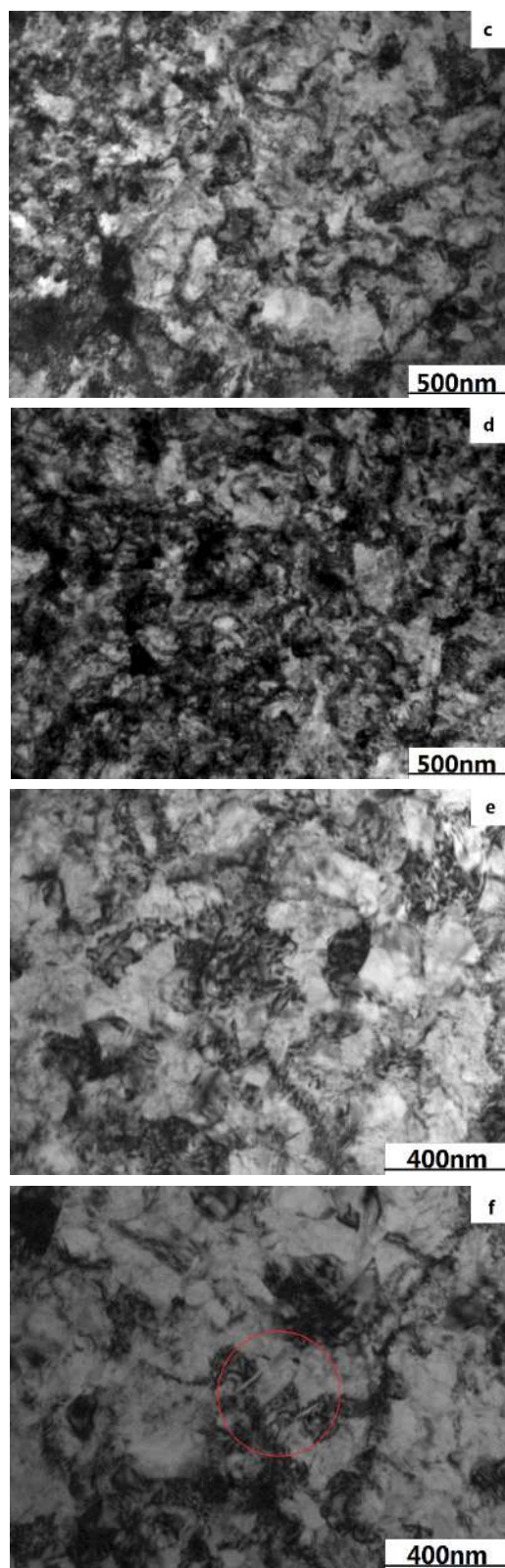
**Figure 8.** The TEM microstructures of commercial pure titanium flat wire after nine-pass rolling process

## 3.3 Cold Rolling Deformation Mechanism of Industrial Pure Ti Wire

The plastic deformation of pure Ti is complicated. It is difficult to satisfy the deformation conditions of the five independent slip systems in plastic deformation by simple type slip. It is necessary to open the slip-like system on the cone or to accompany the twin deformation at the same time. As two main plastic deformation modes of dense hexagonal metals, slip and twinning compete with each other and complement each other [5]. In the microstructure with large deformation, there are few twins, a large number of dislocation entanglement and substructure are distributed in the microstructure, and a large number of fine equiaxed crystals are formed. The evolution rule of microstructure is as follows: in the initial stage of deformation, some grains in the microstructure take the lead in the dislocation slip due to the dominant orientation, and the slip system which is easy to slip is first opened, and when the movement of dislocation slip is obstructed, the movement of dislocation slip is blocked. A large number of dislocations will be plugged into the barrier, resulting in stress concentration and interruption of slip. In this case, the height of stress concentration will cause the shear stress to be higher than the critical shear partial stress required for twin deformation, thus inducing the formation of twins. Twinning is a kind of shear change. Shape, the essence of which is to change the orientation of the crystal so that it rotates to a position conducive to slip, so that the previously stopped or unopened dislocation motion retakes place, allowing the plastic deformation to continue, and in addition, the twins can absorb some of the energy. The local stress concentration is alleviated, the crack is restrained, and the flexibility of the material is increased. With the increasing of accumulated deformation and density of dislocation, the stress concentration becomes more and more obvious, the high

stress makes twins continue to form, and when the rotation of crystal is not ideal, the twin will continue to occur, and the stress concentration is more and more obvious, and the twinning will continue to occur when the orientation rotation of the crystal is not ideal. The size of the crystal will also continue to decrease until it is rotated to the appropriate orientation, when the crystal changes from hard orientation to Due to the soft orientation and more slip systems, the mutual motion of the slip system makes the crystals cut each other, and a large number of dislocations will be entangled at the grain boundary to form dislocation walls or dislocation cells, and the dislocations will decrease the density by rearrangement or cancellation. In the process of deformation, the original grain is divided into a large number of fine grains in order to coordinate the deformation. Under the action of external force, the large angle orientation between the grains will be poor through the rotation of the fine grains. Small equiaxed grains are formed in the local region. At this time, twins are rare in the tissue, and a large number of high-density dislocations are distributed in the tissue. Apart from the dislocation slip and twinning mechanism mentioned above, the plastic deformation lifting of pure Ti is carried out. In addition, grain rotation and grain boundary sliding also promote the plastic deformation of pure Ti, which not only maintains the original grain shape of α phase but also coordinates the slip deformation.

## 4. Conclusion

The main results are as follows:

(1) under the condition of this experiment, the diameter of Φ 2.50mm warm-drawn industrial pure Ti round wire was adopted, and the flat Ti wire with the cross-section size of 0.63mm × 5.03mm was obtained by cold nine continuous rolling.

(2) during the deformation process, the tensile strength and microhardness of the wire increase with the increase of the deformation amount;

(3) during the cold rolling deformation of industrial pure Ti wire, the grains in the microstructure keep equiaxed at the same time, and there are a lot of dislocations and a few twins in the deformed structure.

(4) the main deformation mechanism of pure Ti at room temperature is the slip and twinning mechanism in the small deformation stage, the slip mechanism in the gradual increase of cumulative deformation, and the slip mechanism in which the accumulated deformation increases gradually. And the grain rotation and grain boundary sliding mechanism of auxiliary deformation during rolling deformation.

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## ARTICLE

# An Inquiry into the Application and Preparation of Surfactant in Oil Field

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| ARTICLE INFO | ABSTRACT |
|---|---|
| | As a commonly used chemical agent, surfactant is used to improve the efficiency of oil-and-gas exploitation. Since the conventional surfactant technology fails to meet the requirements of oil-and-gas resources exploitation currently, this paper deeply researches on the studies of cutting-edge technology of oil-and-gas exploitation, and learns the advanced experience from foreign countries. It aims to point out that the needs of China's demand for oil-and-gas exploitation can be met with through technology innovation, preparation methods improvement and key technology mastery of surfactant in oil field. |

## 1. Preface

With the increasingly rising of China's economy, the manufacturing and industry develop rapidly. The development of all industries cannot do without plenty of energy, especially the oil-and-gas resources. China's oil-and-gas resources mainly rely on imports. Up to now, the development of oil-and-gas resources in China mostly features in complex fault block storage, which is difficult to exploit. Due to many complex reservoirs fail to meet the production demand with conventional technology, the oil-and-gas resources are not fully utilized in China. Although the use of surfactant can improve the efficiency of oil use, the original surfactant technology may not meet the requirements. As a result, it is essential to develop and then further improve a new surfactant system.

## 2. Analysis of the Application of Surfactant in Oil Field

The application of surfactant used in oil field needs to be analyzed in combination with the present situation, and a new preparation scheme should be made before the preparation of new type surfactant:

### 2.1 Researches on New Type Surfactant

This new type surfactant is mainly to study the structure, synthesis, compound preparation and industrialization of surfactants. The scheme of the active surfactant is mainly to design the overall structure of the surfactant by means of theoretical analysis, molecular simulation and model compound technology. Moreover, the main task is to design efficient molecular

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structure of salt-resistant surfactant, through which the compound system of surfactant with salt resistance can be established. In this case, it can evaluate the performance of surfactants, optimize the structure of products through product quality inspection. After a successful experiment, the industrial production equipment can be picked out to industrialize the surfactant [1].

## 2.2 Preparations of New Type Surfactant

There are many ways to prepare this new type surfactant. Firstly, the preparation process of new type is more complex, which requires a detailed overall planning to study some contents of surfactant, especially molecular design and synthesis. Secondly, the active surface involves the interdisciplinary knowledge of many fields and disciplines, especially the integration of theoretical chemistry, physical chemistry, organic synthetic chemical engineering and so on. Not only that, in order to improve the oil recovery efficiency and reduce the waste of oil-and-gas resources, the most outstanding characteristics should be innovative, especially in technology [2].

## 2.3 Performance Advantages of New Type Surfactant

The performance of the new type surfactant is much better than that of the conventional type. Firstly, the new type adopts the present synthesis technology, designs the highly effective surfactant molecular structure, optimizes the process parameters, and conforms to the green scientific design. Secondly, the solubility and interfacial tension of the new type were optimized based on the original fundamental conditions. Moreover, the new type is also calcium-and-magnesium resistance, which can improve the oil displacement performance. In addition, the new type has little payable losses, which can improve the oil recovery efficiency of surfactant [3].

## 3. Preparation Project of New Type Surfactant

To develop a preparation project of the new type surfactant, we must have a full understanding of the oil field. It is essential to strengthen technological innovation to improve the efficiency of production.

### 3.1 Structure Design of New Type Surfactant

The structure design of new type must meet higher standards. Due to the imperfect interaction theory be-

tween surfactant and crude oil, it is difficult to design the molecular structure of surfactant. The molecular structure should be designed by means of molecular simulation, theoretical analysis and model compounds, and the "structure-activity relationship" should be completely designed. In the designing process, alkyl benzene sulfonate and alcohol ether sulfonate are used as the main structural objectives, which can optimize the length-and-branching structure of lipophilic end carbon chain, and the length and arrays of ethoxy and propoxy. In the process of design, the molecular structure of the surfactant with high efficiency and salt-resistance is the design goal, and a modern synthesis technology is used to optimize the process parameters to ensure the surfactant performance in the interfacial tension and energy [4].

### 3.2 Compounding System of New Type Surfactant

For both the compounding system and the molecular structure of this new type surfactant are more complex, we should give full play to the advantages of different surfactant, and ensure the requirements of compounding mechanism and law in the process of compounding. In particular, it is necessary to study the interaction mechanism and law with cheap sulfonate surfactant, which can reduce the cost. In order to give full play to the advantages of different oily surfactant, it is necessary to study the parameter equilibrium relationship among the interfacial tension, thermal stability and adsorption performance of surfactant, so as to form surfactant with high temperature and salt-resistance. A new type of active agent can be developed with help of the green raw material with low cost and the green synthesis circuit [5].

### 3.3 Performance Evaluation of New Type Surfactant

The requirements for the performance of new type surfactant are higher and more diversified. Firstly, we need to design a project to test the solubility, interfacial tension, calcium and magnesium resistance of new type surfactant. Secondly, it is essential to strengthen the simulation test of compatibility with polymer, thermal stability and repair loss. In addition, it is also necessary to evaluate the regional performance of salt-resistant surfactant under reservoir conditions. By means of the preparation of perfect laboratory reaction and verification of experimental results, the formula and process parameters were further optimized to study the influ-

ence of the characteristics of these materials on the re-action process [6].

### 3.4 Industrialization of New Type Surfactant

In case the experimental results of the new type conform to the expected experimental objectives and results, the raw material ratio and process parameters can be carried out in the production process. Some advanced technical equipment can be introduced to improve the product conversion rate of surfactant and reduce the cost of surfactant. Suppose the production cost of surfactant is reduced, the production scale can be expanded and the industrialization of new surfactant can be realized. By improving the relevant supporting industry system of new surfactants, the quantitative production can be realized and a certain market share can be occupied. In the future development process, the industrialization of new surfactants will be further promoted by increasing the technology and capital investment.

## 4. Technical Analysis of New Type Surfactant

We need to analyze the technical difficulties of the new type, and master the key points of this new technology.

### 4.1 Innovative Technologies for the Application of New Type Surfactant

The new type mainly adopts a design of molecular structure with salt-resistance. Due to the high mineral concentration of formation water, it is necessary to develop a salt resistant surfactant. In the molecular structure design, the molecular structure of calcium and magnesium resistance are required as the goal. Secondly, the new surfactant also adopts a green synthesis design of surfactant. By using modern synthesis technology, the arrangement of molecular structure is optimized, which makes the synthesis process more economical. In addition, a highly effective compound surfactant used can reduce the cost of surfactant and further optimize the performance of surfactant [7].

### 4.2 Analysis of Key Technologies in the New Type Surfactant

Because of the high requirements on the performance of this new type, it is important to grasp the technical points. Mainly, it must be ensured that the tension of synthetic surfactant reaches a certain standard, with salt-resistance higher than 30000 mg / L, and resistance to calcium-and-magnesium ions of 1800 mg / L. In addition, it should be noted that the interfacial tension requirements of surfactant complex system are different from various reservoirs. The interfacial tension of surfactant compound system needs to meet with higher standards. The other salt resistance is consistent with the resistance to calcium-and-magnesium ions. In addition, it also needs to meet the requirements of thermal stability and adsorption capacity.

### 4.3 Technical Difficulties of New Type Surfactant

Due to the complex petroleum system, the structure of surfactant is complex and diverse, the technology of new surfactant is difficult in the aspects of molecular structure, synthesis route and complex surfactant system:

### 4.3.1 Technical Difficulties in Designing the Structure of New Type Surfactant

The main technical difficulty of the new surfactant lies in the structural design technology of the new type. It is more difficult to design the molecular of the surfactant which calls for stronger salt-resistance. Moreover, the interaction theory between surfactant and crude oil is not perfect, which are still not confirmed in the design. Molecular simulation needs to use molecular simulation theory to analyze model compounds and other means to analyze the structure relationship of surfactants. Thus, it is important to optimize the length of the carbon chain at the lipophilic end and the length and arrays of the molecules [8].

### 4.3.2 Difficulties in Reducing the Cost of Surfactant

The increase in the cost of surfactant is due to the complex structure of the new surfactant compound system, which is widely used in oilfield exploitation and application, and can be used in all aspects of oilfield development. This brings about the difficulty in lowing cost. The solution lies in improving the synthesis technology of surfactant and expanding the source of surfactant raw materials. On one hand, green raw materials and newly developed catalysts are selected for the green process of new surfactants and the synthesis route of surfactants, which has high economic benefits. On the other hand, it can be solved by expanding the source of surfactant raw materials and some cheap raw materials

with extensive sources. Some ideal raw materials for surfactant have been found in China [9].

### 4.3.3 Difficulties in Designing the Performance of New Type Surfactant

Based on high requirements, the performance of new surfactants needs to be diversified. The high temperature resistance of oily surfactants needs to be improved in addition to its salt resistance. As the depth of oil field is increasing, the high temperature resistance of surfactant also needs to be improved. Besides, under different conditions, the concentrations of calcium and magnesium ions are different It is necessary to give full play to the multiple performance of oily surface area with stability, sterilization and adhesion to soil. Because the structure of surfactant is very complex, it is not enough to rely on a single surfactant to drive oil. Some efficient compounding technology is often adopted to fully play the advantages of different surfactants and avoid disadvantages.

## 5. Application of Surfactant in Different Links of Oil field Exploitation

Surfactant can be used with large amount in many production links of oilfield exploitation, such as drilling and oil extraction. So it is important to analyze the application in different links:

### 5.1 Analysis of Application in Drilling

The surfactant used in drilling is called drilling fluid, which is also known as a complex chemical fluid. It is composed of a variety of chemical treatment agents. Firstly, it is the fluid loss additive, which may cause wall collapse in drilling. In order to reduce large-scale filtration water, this kind of fluid loss additive is widely used in deep wells, special wells and complex wells. For most of the oil exploration conditions are complex, increasing depth of drilling, the traditional drilling cannot meet the needs of operation. Viscosity reducer is a new type of viscosity reducer which can resist high temperature and salt. Another emulsifier is also a kind of drilling fluid which has a wide range of benefits, mainly for unstable drilling formation conditions and some deep drilling geological conditions [10].

### 5.2 Application in Oil Extraction

Surfactants are often employed in oil extraction. In case the phenomenon of water production occurs, two kinds of surfactants, water shutoff agent and non-selective agent, can be used. According to different water layer conditions, non-selective water shutoff agent can be selected if it is a single water layer or a higher water layer. This kind of water plugging agent can effectively reduce the surface tension of water, with a higher effect on the water plugging. In addition, another kind of acidizing surfactant may also be used in the process of oil extraction. This surfactant is mainly used in the process of dissolving rocks and expanding oil-and-gas reservoirs, which can delay the rate of acidizing. In addition, surfactant for oil displacement is widely used in the stage of crude oil exploitation. Currently, for this kind of surfactant cannot meet the demand, it is necessary to improve the salt resistance and efficiency of oil extraction.

### 5.3 Application in Oil Transportation

Surfactant also plays an important role in the transportation of crude oil. The main applications are weak solvent for emulsified crude oil and viscosity reducer for crude oil gathering and transportation. The fluidity of crude oil needs to be changed for the transportation difficulty will be increased for the crude oil transportation conditions of high viscosity and poor fluidity. The use of emulsified viscosity reducing surfactant, a water-soluble surfactant, can change the tension of crude oil. This method is advanced in lower cost, larger-scale use, and more convenience.

## 6. Conclusion

Some natural advantages in the natural environment need to be utilized. But we should live in harmony with this natural resource, save energy in the environment and reduce dependence on imported oil and gas resources. We should correctly use this kind of oil and gas resources, reduce the waste of oil and gas resources in the process of exploitation, and correctly apply the oil and gas resources to the industry and manufacturing industry. In particular, we need to pay more attention to the resource exploitation in these fields than before, to the upgrade technology in the preparation process of surfactants, and take every opportunity to exchange and study abroad to enhance the independent research ability of technicians. Meanwhile, we also hope that the government and enterprises will increase investment to help us master the core technology of surfactant.

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This document provides some guidelines to authors for submission in order to work towards a seamless submission process. While complete adherence to the following guidelines is not enforced, authors should note that following through with the guidelines will be helpful in expediting the copyediting and proofreading processes, and allow for improved readability during the review process.

## Ⅰ. Format

- Program: Microsoft Word (preferred)
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- Paragraph: Justified
- Required Documents

## Ⅱ. Cover Letter

All articles should include a cover letter as a separate document.

The cover letter should include:

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- A brief description of the novelty and importance of the findings detailed in the paper

Declaration

v Conflict of Interest

Examples of conflicts of interest include (but are not limited to):

- Research grants
- Honoria
- Employment or consultation
- Project sponsors
- Author's position on advisory boards or board of directors/management relationships
- Multiple affiliation
- Other financial relationships/support
- Informed Consent

This section confirms that written consent was obtained from all participants prior to the study.

- Ethical Approval

Eg. The paper received the ethical approval of XXX Ethics Committee.

- Trial Registration

Eg. Name of Trial Registry: Trial Registration Number

- Contributorship

The role(s) that each author undertook should be reflected in this section. This section affirms that each credited author has had a significant contribution to the article.

1. Main Manuscript

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Supplementary figures, small tables, text etc.

As supplementary data/information is not copyedited/proofread, kindly ensure that the section is free from errors, and is presented clearly.

## Ⅲ. Abstract

A general introduction to the research topic of the paper should be provided, along with a brief summary of its main results and implications. Kindly ensure the abstract is self-contained and remains readable to a wider audience. The abstract should also be kept to a maximum of 200 words.

Authors should also include 5-8 keywords after the abstract, separated by a semi-colon, avoiding the words already used in the title of the article.

Abstract and keywords should be reflected as font size 14.

## Ⅳ. Title

The title should not exceed 50 words. Authors are encouraged to keep their titles succinct and relevant.

Titles should be reflected as font size 26, and in bold type.

## Ⅳ. Section Headings

Section headings, sub-headings, and sub-subheadings should be differentiated by font size.

Section Headings: Font size 22, bold type

Sub-Headings: Font size 16, bold type

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The introduction should highlight the significance of the research conducted, in particular, in relation to current state of research in the field. A clear research objective should be conveyed within a single sentence.

## Ⅵ. Methodology/Methods

In this section, the methods used to obtain the results in the paper should be clearly elucidated. This allows readers to be able to replicate the study in the future. Authors should ensure that any references made to other research or experiments should be clearly cited.

## Ⅶ. Results

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this section. Alternatively, Results and Discussion can also be combined to a single section.

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This section offers closure for the paper. An effective conclusion will need to sum up the principal findings of the papers, and its implications for further research.

## Ⅹ. References

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## Ⅺ. Glossary of Publication Type

J = Journal/Magazine

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C = (Article) Collection

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Equations should be aligned to the left, and numbered with in running order with its number in parenthesis (aligned right).

## Ⅻ. Others

Conflicts of interest, acknowledgements, and publication ethics should also be declared in the final version of the manuscript. Instructions have been provided as its counterpart under Cover Letter.

# Organic Polymer Material Research

## Aims and Scope

*Organic Polymer Material Research* is an international open-access journal. The journal aims to promote research and innovations in the field of organic polymer material science. The journal is a peer-reviewed quarterly publication.

The scope of the Organic Polymer Material Research includes, but is not limited to:

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- Natural polymers
- Conductive polymers
- Smart polymers
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