Effect of Symmetric and Asymmetric Rolling Processes on The Microstructure and Mechanical Properties of AZ31B Magnesium Alloy

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Abstract. Microstructure progression, in addition to excellent plasticity possessions of AZ31B-alloy procedure using four paths in asymmetric through various reductions, was studied to facilitate develops the deprived plasticity of alloy. The procedure was used for alloy of about 78µm grain size, with a prim thickness of 5mm. It was formed by using different ratios, 1:1, 1:1.4, 1:1.8 and 1:2.2. The thinning were 20%, 25%, 30%, 35% to reduce thickness to 4.00mm, 3.750, 3.500, and 3.2500 repetitively. The rolling method was completed by using equal rollers diameter at a constant temperature of 473 K and devoid of lubricating after heating the rollers to 373K; the method was finished through four routes. Path (U.D.), pattern “way was kept” stable and unmoved connecting continual passes; whereas pattern was turned 180o to direction connecting continual passes during path (R.D.); pattern (N.D.) was turned throughout 180° concerning the standard direction to the continual passes; pattern (H.Y.) was turned 180o to the rolling direction primary in addition to, subsequently turned 90° concerning the standard direction connecting continual undulating passes. A traditional rolling process was done under identical situations to evaluate the outcome; microhardness test was also completed. Visual microscopy was used to study of rolling parameters on the microstructure of the rolled pieces. The outcome of inspection explained to the alteration of the microstructure had been pretentious employing path, ratio and decrease area. At low proportion, large numbers of mirror image creation become visible, as reduction raises dynamical recrystallization happening on the identical twin and shear bands were encouraged. In contrast raised proportion caused a raise within the quantity of recrystallized grains furthermore improved the microstructure. Very fine grains construction had been improved while the alloy was rolled using H.Y. path at a proportion of (1: 1.8) and 25% decrease. Excellent plasticity possessions of patterns devoid of annealing were experienced in stress at 673.00 K along with next to room temperature at primary strain selection from 1×10⁻³ s⁻¹ to 2.2×10⁻³ s⁻¹.

Keyword. Severe plastic buckle, Differential speed rolling, AZ31B, Different routes.

1. Introduction

Processes such as extrusion and rolling produced the grain sizes between 3 and 20 µm. To get a more acceptable size, severe plastic deformation methods such as equal channel angular pressing (ECAP) high-pressure torsion (HPT) accumulative roll bonding (ARB) and asymmetric rolling have. They have been used [1]. These methods have to be useful for achieving significant grain refinement down to the sub-micrometre variety, and the grain structures are more delicate than those achieved in...
usual thermo mechanical processing [2]. A numeral of researches have been carried out to undertake the macrostructure, mechanical possessions, of the variety of materials made-up via a (DSR) method in which dissimilar turning velocities of higher and lower rolls are applied, in order that the shear’s strain could be enforced along the pattern caused by the asymmetric buckle description, [3]. The results of these studies show that the grain refinement produced leads to a change in mechanical properties and keep away from the distort instability [4]. A method for fabricating high rate super plastic Magnesium alloys by using elevated - speed ratio was planned. The ingot-metallurgy processed Mg alloy exhibited a super plastic recital equivalent to that of powder metallurgy parts [5]. By optimizing the controlling parameters in the rolling procedure, an ultrafine-grained microstructure with superior thermal stability, which is the required microstructure for achieving (HSR) excellent plasticity, may be obtained. Lately to organize the rolling procedure a few studies concentration on the macrostructure development in addition to warp apparatus through elevated velocity rolling of Mg alloys [6]. In this work, an alike undulating method by unlike rolling velocity proportion of higher and minor rolls moreover dissimilar meting out the list is recommended to decrease the granule dimension, and develop excellent plasticity actions of Mg alloy leaf underneath elevated rates.

2. Experimental

2.1. The beginning substance

The substance in the present work is AZ31B with dimensions (100.00×50.00×5.00) mm³ produced through (Mg alloy Germany Flach produkter,). Chemical composition of the pattern is exposed in the table (1). A theses substance is violently used in construction request, as a result of light heaviness and elevated permanence.

| Table 1. Chemical composition of pattern. |
| Element | AL | Zn | Mn | Zr | Cu | Si |
| %       | 2.67 | 0.679 | 0.369 | <0.001 | <0.001 | 0.0233 |
| Element | Fe | Ni | Ca | Sn | Pb | Mg |
| %       | 0.00292 | <0.001 | <0.001 | <0.005 | <0.005 | 96.24 |

2.2. The rolling scheme

The element of the device contains two undulating, carried on the thrust bearing fixed over the structure. To assist the necessary undulating state, the designer is added four units to the undulating engine which are: higher roll velocity unit, minor roll velocity unit, manage unit designed for a gap as well as reheating unit.

2.3. Rolling operation

A piece of (100×50×5) mm³ cut as of the established Mg alloy in the identical undulating way previous to undulating the piece was heated to 473K for 30.00 minutes in an electric furnace. Then the piece was fed in the middle of spins devoid of via oil. DSR method was completed utilizing unlike decrease area (20.00, 25.00, 30.00, and 35.00) % at remarkable spin revolution proportion linking the upper and minor spins various from 1:1, 1:1.4, 1:1.8 and 1:2.2 using similar roll diameter (150mm). In addition to the velocity of the minor spin was predetermined at (5.000) revolution per minute, whereas upper spin was turned at a various velocity, the rollers were heated to 373K by exceptional heating unit, linked through the thermometer. Connecting every surpass, the pieces were previous heating to fifteen min. Into electric furnace in addition to re-undulating scheme according to the path. For evaluation, the usual undulating was done at similar states. The procedure is repeated in anticipation of arriving at to finishing dimensions using a numeral of surpasses, the requirement of the undulating procedure is revealed into (Table 2).
Table 2. The requirement of rolling procedure.

| No. | Width | Decrease | Numeral passes | Decrease by pass | Closing width |
|-----|-------|----------|----------------|-----------------|--------------|
| 1.0 | 5.0   | 20.0     | 8.0            | 0.1250          | 4.000        |
| 2.0 | 5.0   | 25.0     | 10.0           | 0.1250          | 3.750        |
| 3.0 | 5.0   | 30.0     | 12.0           | 0.1250          | 3.500        |
| 4.0 | 5.0   | 35.0     | 14.0           | 0.1250          | 3.250        |

2.4. Vickers hardness test

Hardness investigations were performed on the refined pattern using (Vickers) technique. The experiment was prepared by use weight of 100.00g (0.981Neoten) as well as (0.333) minute to settle time. The hardness digit was established by using the equations [7]

\[
H_v = 1.8544 \times \frac{P}{d_{av}^2}
\]

Wherever; \(H_v\): Vickers hardness (Mpa), \(P\): applied load (N), and \(d_{av}\),average oblique distance end to end of the groove(mm).

2.5. (Shear) sprain as well as alike sprain after undulating

Utilizing a harden marker, at exactly position lines wherever scratched lying on the side face of the piece before undulating as in (Figure 1). These symbols served as internal symbols during undulating. After undulating, put in scratch can be without difficulty full out, along with the (lineation) dented lying on its side face can exist visibly observed. It is noticeable that throughout DSR undulating, the(lineation) that is perpendicular to the undulating plane before undulating be inclined to towards the undulating path. These are notable; because the preference of (lineation) symbolizes the further (shear) buckle of DSR undulating Figure (2) this symbolizes the truth that (shear) buckle is assumed to be the critical cause of grain enhancement. By comparing in symmetric rolling shown in Figure (3) non-preference of (lineation) is experiential unmoving as soon as the reduction increases while the decrease persist in raising the scrapes to be inclined to curve to figure form. These figures entail that through symmetric undulating non-extra (shear) buckle exists, directly by inspection and depicting the shear strain and the same sprain can be measured from the equation [8].

\[
\epsilon_{eq} = \frac{2}{\sqrt{3}} \sqrt{\epsilon^2_{yy} + \frac{1}{4} \gamma^2_{yz}}
\]

Where; \(\epsilon^2_{yy}\) = compressive strain in ND, \(\epsilon_{yz}\) = ln \(\frac{h_1}{h_0}\), \(h_1\) = closing width, \(h_0\) = original width \\
\(\gamma^2_{yz}\) = shear sprain in ND plane and RD plane, \(\gamma_{yz.0} = \frac{\lambda 0}{h1}\) = tan \(\theta x\), \(\lambda 0\) = neighboring surface, \(\theta x\) = (inclination) position past undulating.

**Figure 1.** Piece before rolling.
2.6. Microstructure examination
A sampling with rough lengths of 10,000 mm was cut off from spanned on a milling machine. (Grinding) was completed using silica polish, before polishing the sampling to eliminate the irregular surface. After the grinding step, the sampling was (swept) through alcohol also dried out through warm (air), go after by the Polishing technique. Because (Mg) is water perceptive, therefore every the (polishing) postponement in addition to lozenge products used in the polishing were alcohol/oil based. After grinding, the face of the sampling was (mirror-finished). The pattern was etched in an acetic picric acid solution (5.2g picric acid, 15ml acetic acid, 75ml ethanol, and 15ml distilled water). It was left on the surface for 6-12 seconds, and they were cleaned thoroughly in (ethanol) and desiccated through warm air’s.

2.7. Tensile investigation
In this work, the excellent plasticity performance of spinning patterns is studied by the tensile investigation. Tensile investigation patterns were cut from spanned pattern alongside plane corresponds with undulating way. The investigations were carried out at temperature 673K, at various sprain duty in the range of (1×10⁻³ to2.11×10⁻³). A particular holder was fabricated to fix the tiny (tensile) sample and to prevent it from slipping.

3. Results and discussion

3.1. Vickers hardness

3.1.1. Vickers hardness along normal and rolling direction. The hardness worth across the pattern thickness as the purpose of reduction in DSRd and ESRd patterns in the normal direction, are shown in table (3). The hardness values increased clearly up on the 20% reduction by the ratio (27%). While ESRd increased by the ratio (12.8%), The fast increase of micro hardness at 20% reduction may be attributed to strain hardening as an outcome to sub grain margins formation, disarticulation density and grain refinement [9]. The following passes cause to noteworthy changes of the hardness in patterns of DSRd. The refined fraction increased and the grain size decrease with the numeral of DSR passes up to arrive at 25%. The hardness increased quickly with the numeral of DSR passes up to 30%
decrease and continuous increased slightly with numeral of DSR pass up to 35%. It should be noted that the values of hardness in normal direction were higher compared to rolling direction values, due to the additional strain hardening effect which as a result of friction between the free pattern rim and rolls.

Table 3. Allocation of Vickers hardness next to the plane of DSR patterns, rolled at 473K, normal direction.

| Path | Velocity (r.p.m) | Velocity ratio | Reduction% | Hardness |
|------|-----------------|----------------|------------|----------|
| UD   | 5               | 1:1            | 20         | 79.26    |
| UD   | 5               | 1:1            | 25         | 80.12    |
| UD   | 5               | 1:1            | 30         | 82.29    |
| UD   | 5               | 1:1            | 35         | 83.49    |
| UD   | 7               | 1:1.4          | 20         | 91.35    |
| UD   | 7               | 1:1.4          | 25         | 93.36    |
| UD   | 7               | 1:1.4          | 30         | 97.85    |
| UD   | 7               | 1:1.4          | 35         | 98.66    |
| UD   | 9               | 1:1.8          | 20         | 90.25    |
| UD   | 9               | 1:1.8          | 25         | 93.31    |
| UD   | 9               | 1:1.8          | 30         | 98.11    |
| UD   | 9               | 1:1.8          | 35         | 100.31   |
| UD   | 11              | 1:2.2          | 20         | 91.43    |
| UD   | 11              | 1:2.2          | 25         | 93.31    |
| UD   | 11              | 1:2.2          | 30         | 98.75    |
| UD   | 11              | 1:2.2          | 35         | 103.85   |
| As-received | -         | -              | -          | 70.23    |

As shown above, table (4) explains the changing of hardness as a function of reduction in DSRed and ESRed patterns in the rolling direction. Also, the hardness values are influenced by both grain size, and disorder density, as elevated dislocation density and twins also increase the hardness values. Consequently magnesium alloys, after forming by DSRed offered higher hardness than as traditional one. According to the table (4).The hardness values appeared sharp increase (43%) at 20% and the speed ratio is (1:2.2),This value decrease to (37% and 32%) at ratio (1: 1.8) and (1: 1.4) correspondingly, but the identical speed rolling (ESR) display only (25%). Because the ESR provide rise to a strong basal texture which incomplete the formability. This imposes the high anisotropy in the pattern and adds to the difficulty in deformation accompanied with reduction also DSRed rolled patterns include a relatively superior fraction of shear textures than do traditionally rolled under the identical processing state. The increase of hardness at early passes of DSRed is attributed to strain hardening induced by the procedure, the values continued to increase with increasing in thickness reduction [10]. The maximum hardness value was obtained at 30% reduction which was 49% higher than that in as-received one, we should be noted that the path UD of DSRed at a speed ratio of (1:1.4) confers a maximum hardness value as revealed in microstructure evolution and Taguchi analysis. After many passes beyond 20% reduction, the DSRed leads to superior grained with grater grain boundaries which prevent the motion of the dislocation and cause to the achievement of harder patterns. Also, after many passes of DSRed, cause increasing the disorientation of grain boundaries values. Then by increasing the amount of DSR passes, low angle grain boundaries are changed to high angle grain boundaries. Therefore for when thickness reduction raises, hardness increasing. However, it drops off a little at 35% reduction of DSRed. This experience is because of diffusion in the high level of accumulated strain in patterns of DSR. As a result the disorientation position of grains cannot increase; this case leads to a decrease in hardness values.
Table 4. Allocation of Vickers micro-hardness alongside the plane of DSR patterns, rolled at 473K, rolling path.

| Path | Velocity (r.p.m) | Velocity ratio | Reduction% | Hardness  |
|------|-----------------|----------------|------------|-----------|
| UD   | 5               | 1:1            | 20         | 71.00     |
| UD   | 5               | 1:1            | 25         | 72.73     |
| UD   | 5               | 1:1            | 30         | 75.36     |
| UD   | 5               | 1:1            | 35         | 74.76     |
| UD   | 7               | 1:1.4          | 20         | 89.15     |
| UD   | 7               | 1:1.4          | 25         | 90.70     |
| UD   | 7               | 1:1.4          | 30         | 95.67     |
| UD   | 7               | 1:1.4          | 35         | 90.02     |
| UD   | 9               | 1:1.8          | 20         | 89.33     |
| UD   | 9               | 1:1.8          | 25         | 91.63     |
| UD   | 9               | 1:1.8          | 30         | 93.37     |
| UD   | 9               | 1:1.8          | 35         | 91.29     |
| UD   | 11              | 1:2.2          | 20         | 91.16     |
| UD   | 11              | 1:2.2          | 25         | 92.01     |
| UD   | 11              | 1:2.2          | 30         | 94.93     |
| UD   | 11              | 1:2.2          | 35         | 91.39     |
| As-received | - | - | - | 63.80 |

3.1.2. Vickers micro hardness along the surface of DSR patterns at different states. The micro-hardness increase from 63.8 as received to 96.25 after 25% reduction at ratio (S.R=1:1.8) and it gives the greatest elongation to failure equivalent to 430.5% is connected to grain refinement, created by DSR according to microstructure and picture of the patterns after deformation process under the super plastic state. The dependence of hardness on grain size proofs to the Hall-Petch relationship. On the other hand after (DSR) process for AZ31B alloy, produced ultra fine-grained samples which have the highest hardness especially with applied different routes. The route hydride (HY) produced roughly ultra fine grained about less than 1µm and has the highest micro hardness values while RD, ND and UD routes are lower. Furthermore, it should be noted that, as (S.R) modify to (1: 1.4) and (1:2.2) the route (RD) has the most significant hardness values compared with other routes, Table 5.

Table 5. Allocation of Vickers hardness along the plane of DSR patterns rolled at 473K and different states.

| Path | Velocity (r.p.m) | S.R | Reduction % | Hardness  |
|------|-----------------|-----|-------------|-----------|
| HY   | 7               | 1:1.4| 25         | 88.00     |
| HY   | 9               | 1:1.8| 25         | 96.25     |
| HY   | 11              | 1:2.2| 25         | 92.53     |
| RD   | 7               | 1:1.4| 25         | 91.30     |
| RD   | 9               | 1:1.8| 25         | 91.50     |
| RD   | 11              | 1:2.2| 25         | 93.35     |
| UD   | 7               | 1:1.4| 25         | 90.71     |
| UD   | 9               | 1:1.8| 25         | 91.65     |
| UD   | 11              | 1:2.2| 25         | 92.01     |
| ND   | 7               | 1:1.4| 25         | 89.95     |
| ND   | 9               | 1:1.8| 25         | 90.22     |
| ND   | 11              | 1:2.2| 25         | 90.88     |

3.1.3. Allocation of Vickers hardness on the rapid and slow rolls plane at different states. Significant modify that occurs during width encourage while the spin (S.R) is distorted as of (S.R1:1) to (S.R1: 1.4) and over to (1: 1.8). In case, symmetric (S.R1:1) the (shear) sprains occur equally concerning the centre line of the pattern with close to insignificant worth are at the middle of the pattern. In addition
to (DSR) demonstrates a permanent shear’s sprain incline during the width, major shear’s sprains take place nearby the unhurried spin. As a result the values of micro hardnes for (DSR) procedure homogenous allocation and high in values compared with (ESR). Noted that the changing of (SR) is only just effectual providing both of the impartial points are placed with the buckle area. If one or together of positions (are) located at or outer surface of the buckle region no cause of rising (SR) is expected. The reasonably high values of the hardness of DSRed patterns evaluated to this procedure by further sever plastic deformation methods may be associated to the debauchery of the buckle also resistance heats starting surface of DSRed patterns with elevated surface’s volume proportion to the warm spins, foremost to decrease of (recovery) rate is an accretion of elevated dislocations as the outcome [10]. Table (6) explains the values of the Vickers micro hardness measured on the surface of the fast roll and slow roll of processed AZ31B alloy after applied unidirectional route. The micro hardness has increased from 63.8 to 90.7 HV after DSR process at 25% reduction, and after 30% reduction increase to 95.67HV on the surface of the high speed roll. On the other hand it has increased to 83.65HV at 25% reduction and 91.95HV at 30%, on the surface of a low speed roll at ratio (1: 1.4) consequently high elongation to failure 400% has obtained as display in the picture of the patterns and Taguchi analysis. While the change of S.R to (1: 1.8) and (1: 2.2) the values of hardness decrease slightly as revealed in the Table(6). The micro hardness values for (DSR) process were higher and logically along the direction of the surface, instead of that the strength is reasonably homogeneous within the cross-sectional plane compared with equal speed rolling (ESR). The micro hardness outcome proves bulky shear buckle was induced through (DSR) procedure, and its donation to the whole buckle increased as the width diminution increased, while the ratio was not much changed by (ESR). While the hardness values variation between the upper and lower surface is tiny at 30%, it is large at the 25% reduction.

3.2. Shear strain and equivalent strain calculation

Figure (2) clearly shows (DSRed) pattern, along with the width path shear’s buckle, which could be brilliantly described by (inclination), is not all the same. According to Figure (3), the usual undulating pattern (tends) to demonstrate no inclinations’ of ideational, while DSR spanned pattern tends to predispose towards the rolling direction. For a reason, that vast (shear) sprain is introduced during DSR procedure contrast to the traditional procedure. Generally traditional undulating gives a raise to a strong basal textures’ which reveal low formability at close to room temperature; for the reason that the basal glide coordination hardly becomes active. These induce the elevated usual (anisotropy) in pattern and raise the difficulty in buckle attended with a decrease of thickness’s and go with to a remarkably limited in together of workability and formability close to room temperature. For that reason, it (is) essential to change or weaken the (basal) textures’ for enhancement of the Formability. Table 7. Exposed the worth of obvious shear angles at different reduction [11].

| Path | Velocity (r.p.m) | S.R | Reduction | Typical values |  |
|------|-----------------|-----|-----------|----------------|---|
|      |                 |     |           | Rapid roll face | Slow roll face |
| UD   | 5               | 1:1 | 25        | 72.73          | 60.78        |
| UD   | 5               | 1:1 | 30        | 75.36          | 62.28        |
| UD   | 7               | 1:1.4 | 25 | 90.70  | 83.65 |
| UD   | 7               | 1:1.4 | 30 | 95.67  | 91.95 |
| UD   | 9               | 1:1.8 | 25 | 91.63  | 82.31 |
| UD   | 9               | 1:1.8 | 30 | 93.37  | 91.91 |
| UD   | 11              | 1:2.2 | 25 | 92.01  | 84.30 |
| UD   | 11              | 1:2.2 | 30 | 94.93  | 92.61 |

Table 6. Allocation of average values of Vickers hardness on rapid and unhurried roll plane for DSR pattern rolled at 473K and different states.
The compactness of shear (d’s) IOP Conf. Series: Materials Science and Engineering 1094 (2021) 012143 doi:10.1088/1757-899X/1094/1/012143

| Reduction % | neighboring Side λₘₜ | primary thickness (hₘₜ) | ultimate thickness (hₘₜ) | tendency angle (θ ) |
|-------------|-----------------------|-------------------------|-------------------------|-------------------|
| 20          | 0.58                  | 5                       | 4                       | 8.25              |
| 25          | 0.81                  | 5                       | 3.75                    | 12.19             |
| 30          | 1.07                  | 5                       | 3.5                     | 17.01             |
| 35          | 1.25                  | 5                       | 3.25                    | 21.05             |

Normally, in (DSR), patterns, basil texture’s immobile (exists) with the basil plane’s predispose to several degrees as of the segment flat surface, which collectively by the granule refinement’s is attention to affect the development of ductility. It is quite evident that as soon as the decrease 20 % the corresponding sprain of DSR procedure is lesser than 25% as well as with rising of decrease, the corresponding sprain raises systematically. Moreover, together with the raise of frictions connecting the (rollers) and pattern with the raise of the velocity the same sprain raises, in that order. According to equations’ (4.1) and Table 8 it is sensible that the patterns which have the same strains’ identical to (0.3550) and (0.4480) contain agree to additional sever plastic buckle. In other words, the effect of granule refinement’s is underneath manager of the same strain’s, the one with huge corresponding strain’s must have advanced grains[12]. Overall, the patterns completed by (DSRed) at decrease 25% and over ought to have bulky quantity of minor grains and very superior grained.

Table 7. Dimension of visible shear angle (θ)

| Reduction % | neighboring Side λₘₜ | primary thickness (hₘₜ) | ultimate thickness (hₘₜ) | tendency angle (θ ) |
|-------------|-----------------------|-------------------------|-------------------------|-------------------|
| 20          | 0.58                  | 5                       | 4                       | 8.25              |
| 25          | 0.81                  | 5                       | 3.75                    | 12.19             |
| 30          | 1.07                  | 5                       | 3.5                     | 17.01             |
| 35          | 1.25                  | 5                       | 3.25                    | 21.05             |

Table 8. Shear’s strain and the same strain of DSRed.

| Decrease % | tan (θ) | Tendency (θ) | c, Compression Strain | c, Identical Strain |
|------------|---------|--------------|-----------------------|---------------------|
| 20         | 0.145   | 8.25         | -0.2230               | 0.2707              |
| 25         | 0.216   | 12.19        | -0.2877               | 0.3550              |
| 30         | 0.306   | 17.01        | -0.3567               | 0.4480              |
| 35         | 0.385   | 21.05        | -0.4308               | 0.5450              |

4. Tensile test
Figure (4a, b) demonstrates a picture of the patterns previous to and following undulating and (pulled) at (673 K) with stable early strain’s 1x10⁻³ s⁻¹. It comes into view that the buckle is reasonably consistent moreover no obvious necking took place approximately the rupture and narrow part is controlled during the experiment. The highest elongation of (430.5-387.6) % had been obtained for the patterns spanned by applying repeated undulating using (HY) path at 25% and (1:1.8) proportion. The highest ductility was recognizing when using UD undulating path at 30 % decrease and (1:1.4) proportion. The smallest ductility values had been achieved at the primary rate’s 1x10⁻³ s⁻¹. Finally the smallest ductility had been obtained when using UD path at 20% at the same velocity. The smallest elongation to breakdown values explains that the essential majority factors in the (ductility) of patterns spanned at alike velocity and alike undulating velocity, pulled at the identical rate 1x10⁻³ s⁻¹. On the other hand, it show that the elongation to failure of patterns improved with the raise of velocity and/or with fraction decrease at the identical early sprain and the identical undulating path. As well the patterns elongations improved with the decrease of speed at the similar undulating states. The portion of lookalikes counted on the proportion buckle induces by present request various paths. The stream pressure could be raised when the portion of twinning raised, raised lookalikes (density) would raise the impediment of displacement. Thus the contact among the twin’s (boundaries) as well as the disruption is the main reasons that influence on the run activities of the buckled alloy at low velocity in addition to elevated decrease Figure (5a, b) The elevated worth of stream strain could be accredited to the width reduction and strain (hardening). Dynamic’s recrystallizations may be beginning through raise either reduction or velocity. As well the compactness of shear’s bands in addition to the quantity of (recrystallized) granules raised as both undulating velocity and decrease be raised.

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Figure 4. Tensile samples and elongation for AZ31B alloy after pulling at 400 and constant primary rate $1 \times 10^{-3}$ S$^{-1}$. HY path, b) UD path.

Figure 5. Right stress- right strain curvature for AZ31B patterns rolled at different undulating states. a) HY path, b) UD path.

5. Macrostructure evolution
Figure (6) explains the macrostructure of the regularity in addition to irregularity distorted patterns by path (HY) using (DSR) undulating and decreases. The macrostructure of symmetric undulating at low velocity at 30% reduction explains a great deal twin’s “structures” with a portion of re-crystallized granules expand at the full area of “shear band” and identical limitations give details in Figure (6c). As soon as the velocity in (DSR) improved to (1: 1.4) with condensed “reduction” to 20%, the
The macrostructure consisted of extended granules of dissimilar orientations aligned the length of the shear’s band director, as well as the sum of grains with different sizes formed near the long grains borders. Figure (6a). Rising the undulating velocity, proportion and reduction, an elevated compactness shear’s bands were produced and the “microstructure” seems to be just about full using dynamically re-crystallized granules in the total region, as publicized in Figure (6b). The additional raise in undulating velocity to (11 r.p.m) also “reduction” to 35% and proportion to (1:2.2), a more significant non-homogenous formation otherwise soggy macrostructure had shown. The macrostructure includes dissimilar forms of granules in dissimilar (directions). The initial be tiny re-crystallized granules limited to a small area at the mirror image and among the “shear bands boundaries”. Second is a crude granule created on the “shear bands” allied in various paths as publicized in Figure (6d).

![Diagram](image)

**Figure 6.** Optical macrostructures of rolledAZ31B patterns path HY.

The macrostructure of the patterns rolled by path UD at varied undulating velocity and decrease explains in Figure (7). At a low velocity of (5.00 r.p.m) with reduction20% and 1:1 velocity .It may be noticed to a bulky numeral of lookalikes was produced .also a rough extended granules were “observed” as revealed in Figure (7a) .The macrostructures of patterns distorted by UD path and “DSR” are publicized in Figure (7 b., c. and d). As of the macrostructure, it may be noticed to (shear bands) were created at the together low relative amount and the elevated relative amount in addition to the majority re-crystallized granules be concerted near the (shear’s bands). At what time the pattern
was spanned at 30% and (1:1.4) proportion, notices Figure (7c), shear bands were created; dynamic recrystallization can be observed close to the shear’s “bands”. Rising undulating velocity and decrease to (1:1.8) and 35% in that order, the compactness of shear bands improved and the quantity of recrystallized granules at the twins and shear bands were augmented, the microstructure was virtually completely re crystallized as publicized in Figure (7d). It had been descriptions by Zhang [12] to the look liking bands tend to be limited to a small area extremely stressed areas. The majority “favorable” site for dynamically re crystallization and played a significant function in refinement the macrostructure since they contain superior store up energy. While the undulating proportion was raised to (1: 2.2) and “reduction” decreased to 25%, the compactness of shear’s bands was diminished and wide shear band with rough extended granules have to be created, notice Figure (7b).

![Shear bands, Twins, DRX grains](image)

a) UD, S R 1, Red.20  

b) UD, S R 2.2, Red.25  

c) UD, S R 1.4, Red.30  

d) UD, S R 1.8, Red.35

**Figure 7.** Optical macrostructures of rolledAZ31B patterns path (UD)

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