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The effect of speed asymmetry on the strain state in aluminium bimetals during accumulative rolling

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Abstract. Methods of severe plastic deformation are one of the most modern and cost-effective methods for obtaining high values of mechanical properties in metals and alloys. It is possible to obtain an ultrafine-grained structure due to such processes. The shear component has a significant effect on the value of the true deformation in case of using the methods of severe plastic deformation. In this paper, the strain state of aluminium alloys Al5083, Al1070, and Al2024 in the process of bimetal asymmetric rolling and accumulative rolling was investigated. Symmetrical and asymmetrical rolling of a sample was simulated in the Deform 2D software package. The thickness of the workpiece was 2 mm, the reduction by one pass was 50%, the friction coefficient on the contact of the metal and the rolls ranged from 0.1 to 0.4, the velocity of the rolls was 1.047 rad / s in the symmetric case. The discrepancy between the speeds of the rolls was 10-50%. The presented data agree with the known experimental data on the processing of aluminium alloys, thus the result obtained provide for obtaining the UFG structure in these alloys.

1. Introduction

Methods of severe plastic deformation are one of the most modern and cost-effective methods for obtaining high values of mechanical properties in metals and alloys. It became possible to obtain an ultrafine-grained structure with their help. Such structural changes lead to a significant increase in strength - this parameter increases in 2 times in pure metals and by 40-80% in alloys [1]. The development of severe plastic deformation technologies for industrial and commercial applications is a complex scientific task.

Processing of an aluminium alloy by the severe plastic deformation method makes it possible to refine the metal structure. This leads to an increase in the dislocation density. It is important that the yield stress and tensile strength also show an increase. The crushed grain in such conditions is an indispensable factor for maintaining the ductility of the metal at a proper level. Severe plastic deformation extends the temperature range at which superplasticity is manifested. It should be noted that if the temperature at which the material is processed is low, the smaller will be the grain growth in the structure, which naturally improves the mechanical properties of the material. Also, a high reduction of the strip, which contributes to an increase in the shear strain, leads to a refinement of the grain in the structure.

2. Method of research and materials

In the present research, Al 1070, Al 2024 and Al 5083 alloys were chosen as the material for simulation in the Deform 2D software package. Deform 2D is a forceful system for modeling

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processes of metal forming with the possibility of analyzing a two-dimensional metal flow with the use of the assumption of plane strain. The main goal was to obtain an ultrafine-grained structure in aluminium materials by different means: symmetrical and asymmetrical rolling of bimetals and accumulative rolling. Endeavours of obtaining the ultrafine-grained structure in such bulk materials are currently unsuccessful [2-4].

The mechanical properties of Al 5083 make it possible to use it under extreme conditions in areas such as shipbuilding, aircraft and automotive industries; it has high hardness and strength. Alloy Al 1070 is characterized by high electrical conductivity and corrosion resistance. Alloy Al 2024 is the most famous and most widely used "aircraft" alloy. The chemical composition of the investigated Al 1070, Al 2024 and Al 5083 alloys is given in tables 1, 2, 3 [5,6].

Table 1. Chemical composition of the Al 1070 alloy (wt%).

Si	Fe	Cu	Mn	Mg	Ti	Al
0.15	0.16	0.01	0.03	0.02	0.01	balance

Table 2. Chemical composition of the Al 2024 alloy (wt%).

Si	Fe	Cu	Mn	Mg	Cr	Al
0.422	0.178	0.02	0.019	0.473	0.001	balance

Table 3. Chemical composition of the Al 5083 alloy (wt%).

Si	Fe	Cu	Mn	Mg	Cr	Al
0.40	0.40	0.10	1.00	4.90	0.25	balance

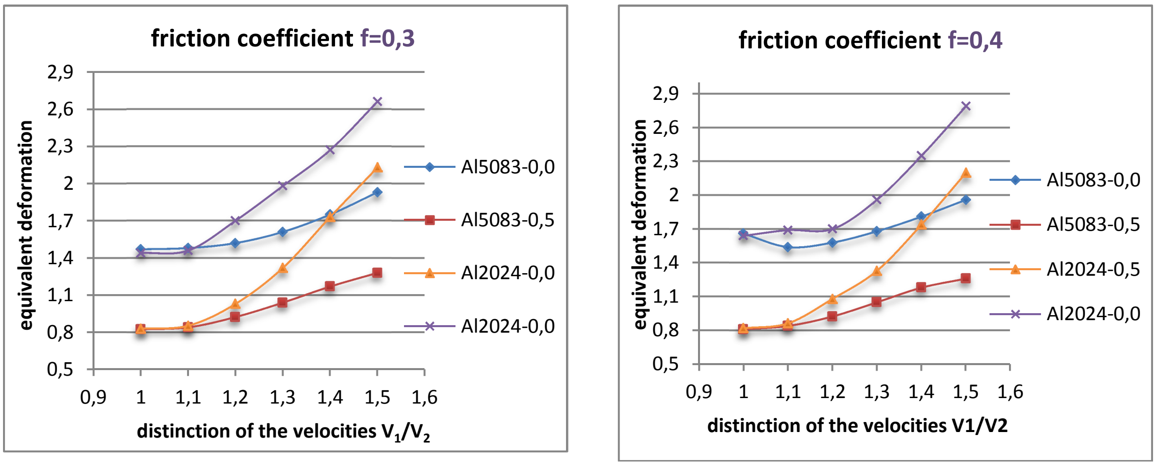
All the parameters that were taken into account as the initial data are given in table 4.

Table 4. Initial data for simulation processes in the soft package Deform 2D.

	Accumulative rolling	Rolling of bimetals
Material	Al5083	Al1070, Al2024, Al5083
The thickness of the workpiece	2 mm	2 mm
The reduction per one pass	50 %	50 %, 60 %
The friction coefficient	0.1-0.4	0.1-0.4
The velocity of the rolls	1.047 rad/s	1.047 rad/s
The distinction of the velocities	10-40 %	10-50 %
Rolls radius	250 mm	250 mm

3. Results

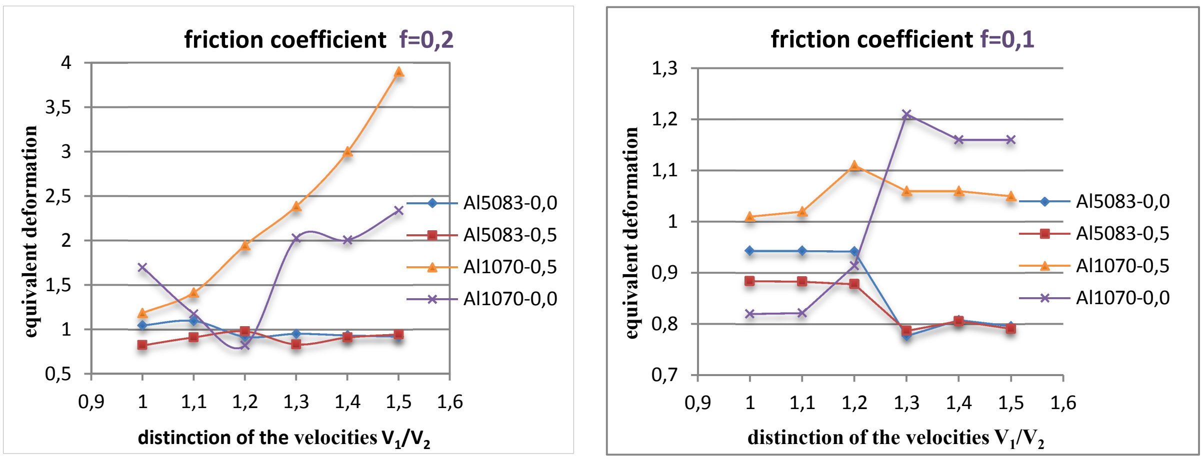
Figure 1 a-b show the simulation results: in the case of aluminium bimetal rolling (top layer is Al5083 and bottom layer is Al2024) with high-speed asymmetry, which had different distinction of velocities, the value of equivalent deformation increases with a friction coefficient of 0.3 and 0.4, it favourably influences the formation of an ultrafine-grained structure. In this case, these values equally increase in the centre (Al5083-0.5 and Al2024-0.5) of the sample and on its surfaces (Al5083-0.0 and Al2024-0.0).



a b

Figure 1. The dependence of the equivalent deformation and the distinction of the velocities of the rolls at a friction coefficient 0.3(a) and 0.4 (b).

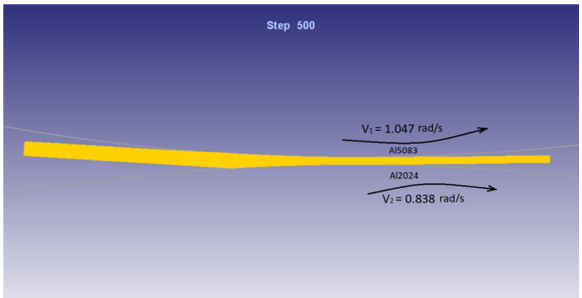
In the case of bimetal processing (the top layer is Al5083 and the bottom layer is Al1070) with identical conditions, the situations changes: with increasing speed asymmetry, the value of equivalent deformation rises with increasing friction coefficient. Al5083 is deformed evenly, while Al1070 shows an abrupt increase in the equivalent strain on the metal contact surface, as shown in figure 2 a-b. It is impossible to unequivocally describe the reasons of the upcoming mechanism. The angle of shear in different metal layers differs, the largest angle takes a value of more than 80 degrees, and the structure is not homogeneous.



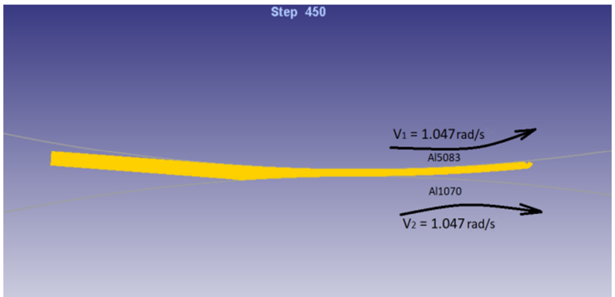
a b

Figure 2. The dependence of the equivalent deformation and the distinction of the velocities of the rolls at a friction coefficient 0.2(a) and 0.1 (b).

The bending of the strip (both the front and rear curtains) varied depending on the velocity of the top work roll, the friction coefficient and the type of the aluminium alloy. This indicates that the reductions along the strip edge are uneven, and the strip alignment occurs if the longitudinal velocity of the top and bottom surfaces of the strip is not the same, which is confirmed by figure 3 a-b.



a



b

Figure 3. The nature of the metal flow at the asymmetrical rolling of the bimetal Al5083/Al2024 (a) and at the symmetrical rolling of the bimetal Al5083/Al1070 (b).

4. Conclusions

In this paper, the role of equivalent deformation during the asymmetrical rolling of bimetals Al5083/Al2024 and Al5083/Al1070 and accumulative rolling of Al5083 with a distinction of velocities of the rolls was considered. It is shown that the value of the accumulated deformation increases due to the nonmonotonic metal flow, especially during rolling of the bimetal (up to 7.5-9). The value of the shear angle φ for asymmetrical rolling of the bimetals is more than 80°, which ensures that the structure enters the zone of severe plastic deformation.

Acknowledgments

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