

New concepts of severe plastic deformation combined processes

Panin E.A.¹, Naizabekov A.B.², Volokitin A.V.¹, Akhmetova G.E.¹, Volokitina I.E.², Tolkushkin A.O.³

¹Karaganda Industrial University, Temirtau, Kazakhstan;

²Rudny industrial Institute, Rudny, Kazakhstan;

³Ural Federal University named after the First President of Russia B.N. Yeltsin, Ekaterinburg, Russia
e-mail: cooper802@mail.ru

Abstract: On the basis of review of last developed combined metal forming processes the new concepts of severe plastic deformation combined processes aimed at further improving the deformation performance are proposed. The presence in all three proposed variants of the ECAP scheme will allow deforming without significantly changing the initial dimensions of the workpiece.

Keywords: METAL FORMING, SEVERE PLASTIC DEFORMATION, COMBINED PROCESSES, ECAP.

In recent years, the principle of implementing severe plastic deformation (SPD) in metal forming is one of the main ways to improve the properties of processed materials by grinding the structure to an ultrafine-grained state. The most well-known classical SPD method is equal-channel angular pressing [1-3] is discrete by its nature and does not allow the deformation process to be carried out continuously, as well as to process large-length workpieces. Because of these two disadvantages, this method still remains investigated only at the laboratory level.

In order to increase the productivity of the ECAP process, it is necessary to get rid of these technological shortcomings. This is possible if the ECAP is combined with other metal forming processes that allow deforming long blanks and having the possibility of continuous deformation, i.e. with the rolling or drawing process. For this purpose, a number of combined deformation processes have been developed in recent years. These include the following processes: "rolling – ECAP" [4] (Fig. 1, a), "screw rolling – ECAP" [5] (Fig. 1, b), "ECAP – drawing" [6] (Fig. 1, c).

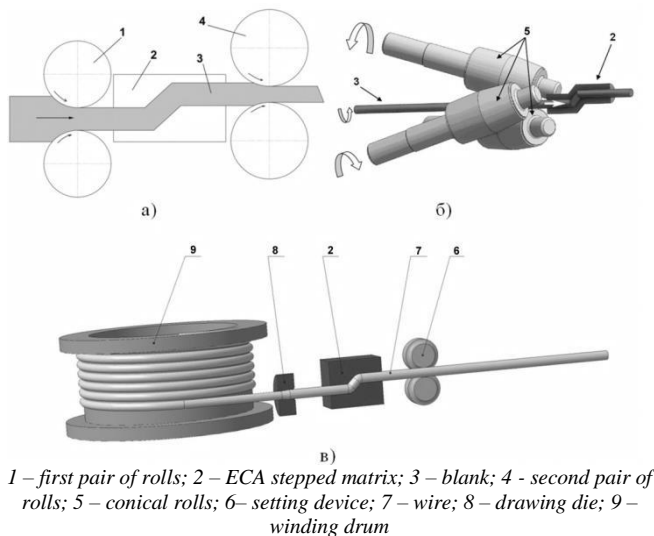


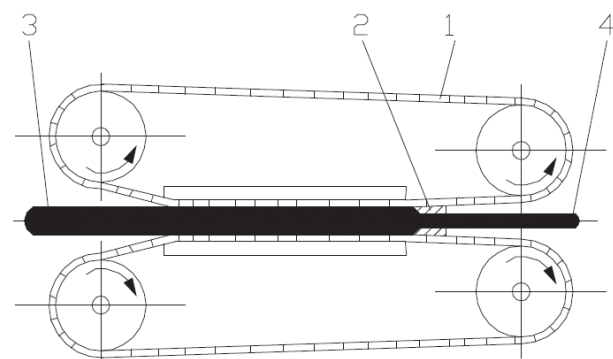
Fig. 1. Schemes of combined processes

When implementing these combined processes, conditions for continuous deformation of unlimited length workpieces are created. Moreover, in the first case, this becomes possible thanks to the rolling rolls installed on both sides of the matrix. The first pair of rolls, due to the contact friction forces, capture the workpiece and push it through the channels of an equal-channel stepped matrix. After the workpiece completely exits the channels of the matrix, it is captured by a second pair of rolls, which also, due to contact friction forces, capture the workpiece and completely pull it out of the matrix. When implementing the combined "screw rolling – ECAP" process, after the workpiece completely leaves the gap of rolls, the next workpiece is fed to them, which, after passing through the rolls and entering the matrix, pushes the previously deformed workpiece out of the matrix.

When implementing the combined process "ECAP – drawing", the pointed end of the wire is set into an equal-channel step matrix,

and then into a calibration fiber, i.e., in essence, the process of metal movement does not differ from the movement of wire in the fiber during the standard drawing process. After the end of the workpiece comes out of the drawing, it is secured with gripping tongs and wound onto the drum of the drawing mill. In this case, the process of stretching the workpiece through an equal-channel step matrix and a calibration fiber is realized by applying a pulling force to the end of the workpiece.

A feature of the Linex method (Figure 2), proposed by specialists of Western Electric Co (USA), is that the pressure required for the implementation of the process is created through the use of active friction forces that arise between the flat surfaces of the links of infinite chains and the upper and lower planes of the workpiece having a rectangular cross section [7].



1- drive chains, 2- matrix, 3- workpiece, 4- product
Fig. 2. Scheme of the continuous pressing process by Linex method

At the same time, the value of the pressing pressure turns out to depend on the ratio (difference) of the friction forces on the non-lubricated and lubricated planes of the workpiece. This method is used for the production of aluminum tires and wire at the factories of the company Vencuck (USA).

It is also possible to combine material processing processes in different aggregate states. In this case, the most well-known method is the combined process of casting, rolling and pressing (Fig. 3) [8]. In this process, the metal in the liquid state is fed to the cooled rolling rolls, which act as a crystallizer. Upon contact with the rolls, the metal hardens, is rolled and pressed through the matrix.

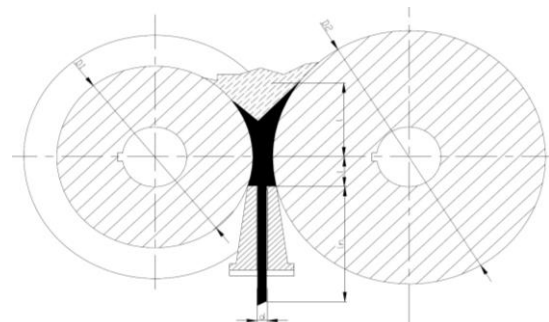
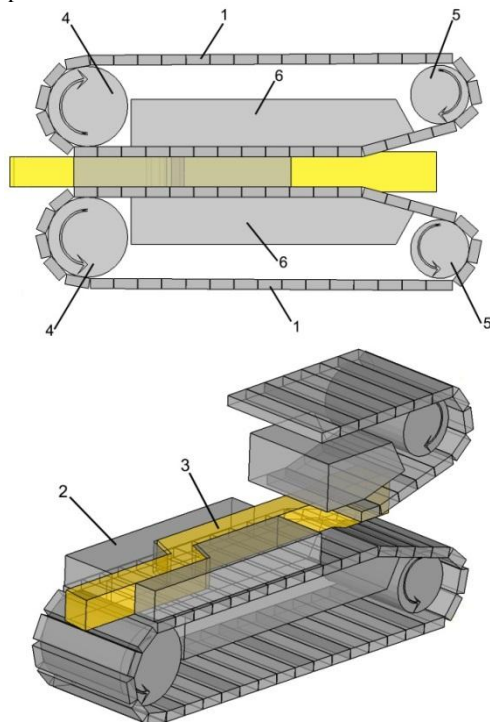


Fig. 3. Combined casting, rolling and pressing process

Based on the analysis of these processes, the following new concepts of combined processes were proposed:

1) combined process "ECAP – Linex" (Fig. 4) for continuous pressing of non-ferrous metals and alloys, the key difference of which from the classical Linex process will be the possibility of deformation without significant change in the initial dimensions of the workpiece.



1 - movable belt blocks, 2 – ECAP matrix, 3 – blank, 4 – idle pulleys, 5 - drive pulleys, 6 - fixed locking blocks
Fig. 4. Combined process "ECAP – Linex"

Deformation in this device is carried out as follows. The heated workpiece is fed to the device, where movable tape blocks grab the workpiece and push it through the channels of the fixed matrix. Each belt gripping block is clad on two pulleys, one of which is idle, and the other is driven by an electric motor. It is due to this that the tape gripping blocks are set in motion. The horizontal forming of the tape gripping blocks is created due to their

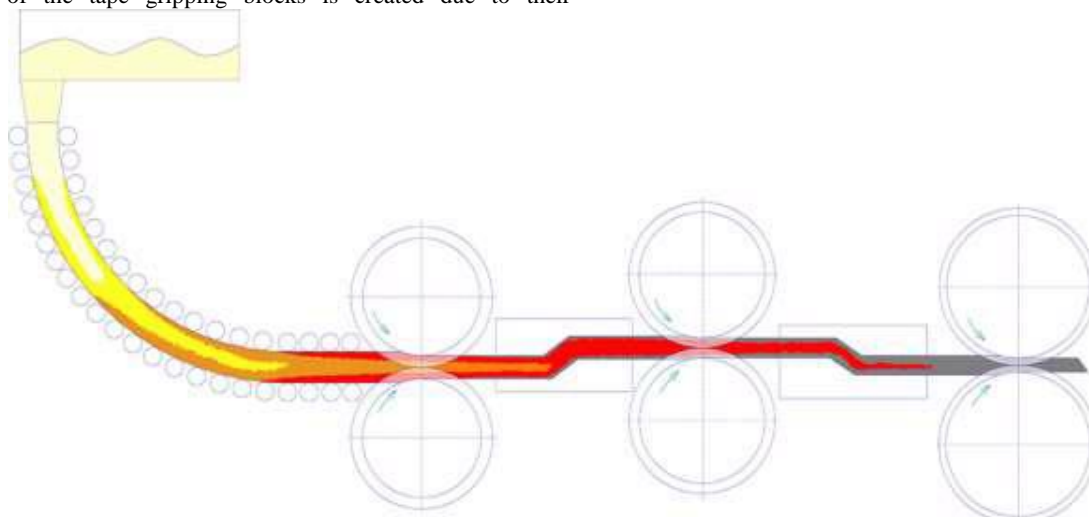


Fig. 6. Scheme of the combined process "casting-rolling-ECAP"

Conclusion

The considered combined deformation processes have significant technological advantages over classical discrete SPD processes. At the same time, they also have certain disadvantages. The proposed new concepts of combined processes of severe plastic deformation are aimed at further improving the deformation performance. And the presence in all three proposed variants of the

movement along the workpiece and fixed locking blocks that perform a clamping role. To reduce the deformation force, grease is applied to the walls of the fixed matrix, while there is no lubricant supply to the moving parts in order to increase the gripping ability.

2) combined process "rolling-ECAP" with combined rolls (Fig. 5). The previously considered rolling- ECAP deformation scheme, despite all its advantages, still has one drawback. With multi-cycle deformation according to this scheme, the workpiece will be compressed several times in height, which as a result will lead to a significant change in the size and shape of the original cross-section, which is often undesirable, and sometimes a negative factor. Therefore, this scheme has been improved by replacing the second pair of horizontal rolls with vertical rolls. Thus, after leaving the matrix, the workpiece will receive compression not in height, as before, but in width. As a result, the change in the shape and size of the cross-section will not be so intense.

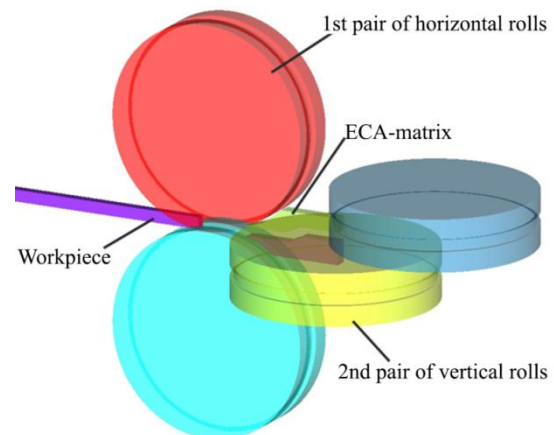


Fig. 5. New scheme of the combined process "rolling-ECAP"

3) combined process "casting-rolling-ECAP". Since the "rolling- ECAP" process itself is quite innovative, it was decided to carry out its further improvement. The proposed process option will include a casting and rolling unit combined with the well-known design of the "rolling- ECAP" process. At the same time, a scheme with two pairs of rolls is possible, as well as with three or more (Fig. 6).

ECAP scheme will allow deforming without significantly changing the initial dimensions of the workpiece.

Acknowledgments

This research was funded by the Science Committee of the Ministry of education and science of the Republic of Kazakhstan (Grant № AP13067723).

References

1. R.Z. Valiev, T.G. Langdon. Principles of equal-channel angular pressing as a processing tool for grain refinement. *Progress in Materials Science*. 2006. Vol. 51. pp. 881–981.
2. Jaeger A., Gaertnerova V. Equal channel angular pressing of magnesium at room temperature: the effect of processing route on microstructure and texture. *Philosophical Magazine Letters*. 2012, Vol. 92, Iss. 8, pp. 384-390.
3. EA patent 1861211. Severe plastic deformation of metals. Rosochowski Andrzej, 2007
4. A. Naizabekov, S. Lezhnev, E. Panin, I. Volokitina, A. Arbuz, T. Koinov, I. Mazur. Effect of Combined Rolling–ECAP on Ultrafine-Grained Structure and Properties in 6063 Al Alloy. *Journal of Materials Engineering and Performance*. 2019, Volume 28, Issue 1, pp 200–210.
5. A. Naizabekov, S. Lezhnev, A. Arbuz, E. Panin. Combined process “helical rolling-pressing” and its effect on the microstructure of ferrous and non-ferrous materials. *Metallurgical Research & Technology*. Volume 115, Number 2, 2018, Article Number: 213.
6. A. Naizabekov, I. Volokitina, A. Volokitin, E. Panin. Structure and Mechanical Properties of Steel in the Process “Pressing–Drawing”. *Journal of Materials Engineering and Performance*. 2019, Volume 28, Issue 3, pp 1762–1771.
7. С.Б. Сидельников, Н.Н. Довженко, Н.Н. Загиров. Комбинированные и сов-мещенные методы обработки цветных металлов и сплавов: монография. - М.: МАКС Пресс, 2005.- 344 с.
8. Lopatina E.S., Biront V.S., Sidelnikov S.B. Metallographic tests of modifying ability of rods from aluminum alloys obtained by combined casting and rolling-extruding. *Journal of Siberian Federal University. Engineering and Technologies*. 2014. Vol. 7. Iss. 2. pp. 127-131.