1. INTRODUCTION

At present a traditional «rhomb-square» pass system is widely used in the process of bar making (fig. 1,a), where both rhomb and square pass on the rolls are placed diagonally relative to the axis of rolls [1]. However when using this pass system there appear substantial nonuniformity in the thickness and width of the rolled strip and excessive grain elongation along the width which results in the formation of anisotropy of mechanical properties in longitudinal and cross directions in the finished product. The reason of this phenomenon is the appearance on the contact surface of the interaction of metal and the pass walls of the so-called «supporting forces» of friction whose vectors are always directed against metal flow, and these forces have a resisting effect on the external
load and increase the overall rolling force and total power consumption. Furthermore, form changing happens because of the compressive strain in thickness and elongation along the longitudinal billet axis with a slight widening of the outer sections of the strip edge in the cross direction. Besides, such action of contact friction forces accompanied by the effect of minor value of the factor of the form of site of origin for strain [2] in the traditional pass systems results in deficient development of plastic deformation in the axis zone of metal, i.e. in the place where the most defect affected sections of the initial ingot and continuously cast billet are located-axis porosity, gas holes, dendrite liquation, etc.

In order to eliminate these defects it would be necessary to apply multipass deformation through the system of traditional passes and sufficient reduction of the cross-section area of the rolled strip which on the whole leads to the reduction of the rolling mill productivity and to the increase of the overall material and power consumption. Moreover, formation of rhomb and square angles in all the runs is connected with the same sections of the deformed strip which results in more rapid cooling of these sections and consequently in more severe wear of the zones of the pass walls which directly contact with the strip angles.

Improvement of metal product quality along with sufficient cut of power and labour costs can be achieved by new metal forming processes realizing intensive plastic deformation (IPD) when less energy is used for deformation, maximum possible and uniform processing of metal cross-section is achieved, obtaining a structure with the given physical and mechanical properties, welding up of discontinuities and so on [3].

A process of realization of intensive plastic deformation in bar making using «rhomb-square» pass system with non-diagonal placement of rhomboid pass relative to the longitudinal roll axis in such a way that two opposite sides of the rhomb are located parallel to the roll axis, and the other two sides of the rhomb at an angle to the roll axis (fig. 1,b) has been developed at metal forming chair of Karaganda state industrial university.

![Diagram](image-url)

**Fig.1.** Kinds of «rhomb-square» pass
Rolling in the proposed «rhomb-square» pass system with a non-diagonal location of rhomboid pass is realized in the following way. The initial cross section billet 1 (fig. 2.) in the first run is fed to the rhomboid pass 2 by the upper and lower bases parallel to the roll axes. In the site of origin for strain the billet is subjected to the intensive shearing strain in cross direction due to asymmetric action of the inclined walls of the rhomboid pass from the side of the upper and lower rolls and high reduction on the cylinder sections of the rolls pass.

As a result the site of origin for strain in cross direction there arise two plastic displacement flows with intensive shear and opposite flow vectors – the shear from the upper roll side goes from the left to the right, and from the lower roll side - from the right to the left. The boundary of separation of these shears is the plain of big rhomb diagonal. Moreover, the inner defects the billet located in the vicinity of this plain are easily eliminated by oppositely directed shear strain. As for as during rolling the centre of this plain coincides with the axis part of the cast billet or ingot, the casting defects such as axis porosity, gas holes and dendrite liquation are subjected to the action of unequally directed shear strains, and these defects split, grind, suffer plain spinning and at the same time are being subjected to compression due to high deformation. All this results in active «healing» of the above defects of the initial metal.

**Fig. 2.** Sequence of rolling in the proposed “rhomb square” pass system with non-diagonal location of the rhomboid pass

Then (the second run) the obtained intermediate workpiece 3 of rhomboid in the square pass 4 by a traditional technique, i.e. rhomboid workpiece 3 is turned counterclockwise at the angle 90°–α (where α is aslope of the long rhomb diagonal relative to the longitudinal roll axis) and feed it into diagonally located square pass 4 with the long diagonal perpendicular to the roll axis. Metal deformation in square pass 4 is realized mainly due to high reduction.
in thickness and limited widening due to the division of the plastic displacement flow relative to the vertical pass symmetry axis.

In the next (third) run the workpiece of square section 5 is preliminary turned at 45° and fed to rhomboid pass 6 with non-diagonal location relative to the roll axis as in the first rhomboid pass 2 but unlike it the inclined pass walls have an opposite grade, i.e. relative to the vertical axis of the workpiece 5 the inclined walls of pass 6 are turned to the left. In this rhomboid pass 6 the sign of shear strain changes for the opposite one relative to the sign of shear strain in the first rhomboid pass 2. The use of alternating shear strain reduces in its turn the intensity of accumulation of metal damage and metal ductility increases in comparison with monotonous deformation. The resultant rhomboid workpiece 7 is turned clockwise at 90°–α as shown in the scheme and rolled in square pass 8 by a traditional technology (fourth run).

Thus the above considered four runs in the proposed "rhomb-square" system make one complete processing cycle with, alternating shear strain and simultaneous high reduction in all four passes. This will make it possible to realize substantial processing of the cross-section in the whole body of the rolled metal and simultaneous reduction of harmful action of contact friction forces in the rhomboid passes. Turning of the workpiece in every following run results in the renewal of the strip angles contracting directly with the pass walls which prevents local overcooling of individual strip sections and this reduces the intensity of the passes wear.

When it is necessary the whole rolling process can be realized in several similar cycles which depends on the relation of the initial billet sizes and finished products, and the requirements imposed for metal quality.

Computer simulation of the stressed and strained state of metal during cross shear showed [4] that in the rhomboid passes with non-diagonal location the strip is subjected to shear strain in opposite directions from the sides of the upper and lower rolls due to the action of the side inclined pass walls which causes a higher level of realization of intensive shear strain in comparison with traditional rolling. During comparative evaluation of the efficiency of processing the deformed metal in the zones of the considered section it was determined that the averaged value of the logarithmic shear strain intensity for a traditional process is 0,354 and for the new one 0,528 which under other equal conditions provides almost 1,5 times increase of the efficiency of metal structure processing. At the same time the new rolling process provides a more uniform distribution of shear strain in the zones of the metal cross sections than a traditional one. The advantages of the new process and the use of alternating strain in the runs will make it possible to achieve the required level of processing metal structure at a less number of runs in comparison with a traditional rolling process. It is quite possible that under other equal conditions of rolling the number of the runs necessary for achieving the required quality of the finished product can be cut to 1,5 times.

The proposed rolling process has been tested in the laboratory conditions on “DUO-220” small section mill where according to the new “rhomb-square” pass system a 30x30 mm square section was made of 50x50 mm 40ch and 70ch steel square billet heated to 950-1150°C in 4 runs. The results of the analysis of mechanical tests of the samples made of these sections shows that in the laboratory conditions during 4 rolling runs there have been achieved the levels of the indicators of mechanical properties which are achieved during much greater number of runs in traditional technology.

The results of metallographic studies revealed the peculiarities of formation the microstructure and thin substructure of the metal rolled by the new process. The subsequent post-deformation cooling and accompanying reverse phase transformations of the deformed austenite into pearlite-ferrite phases on the whole reflect the peculiarities of the deformed austenite structure. However collective static recrystallization cannot begin, and newly formed pearlite and ferrite grains cannot grow to large sizes and on the whole they inherit, though with
some changes for growth, the sizes of the deformed austenite forming at the moment of the completion of plastic deformation [5].

2. RESEARCH RESULTS AND DISCUSSION

On the basis of theoretical and experimental studies of the new process a technology of making reinforced steel 18 mm dia as applied to the conditions of section mill shop of “Arselor Mittal Temirtau” JSC is being developed which is meant to provide sufficient increase of metal quality due to realization of intensive plastic deformation and its joining with thermomechanical processing in technological flow using heat of the rolling operation.

Initial billets entering a group of roughing stands usually have substantial size deviations in comparison with nominal sizes. Furthermore rolling in roughing stands is accompanied by substantial distortions of the forms and sizes of the workpiece end parts. That is why the rolling with realizes intensive shear strains is expedient to carry out in intermediate and finishing stands, particularly for continuous 16-stand mill in 7-14 stands. With all this in view a new system of roll grooving has been developed (fig. 3)

Fig.3. New roll grooving system for making reinforced 18 mm dia steel
As it can be seen from fig. 3 that in realization the new technology of bar rolling it is very important to solve the problem of turning workpieces between the mill stands. First of all it is necessary to determine their installation and designed parameters which include the distance between the axes of the working rolls and turning rollers, the initial angle of turning metal and designed sizes of the working elements of turning rollers. As applied to the proposed roll grooving system there have been worked out the designed sections of the working elements of guide fittings (fig. 4) in view of the designed and technological parameters of the existing rolling line.

![Fig. 4. Sections of working elements of intaking and removing fittings and turning rollers](image-url)
3. CONCLUSION
1. The process of realization of intensive plastic deformation in bar rolling using “rhomb-square” pass system with non-diagonal location of rhomboid pass has been developed.
2. The possibility of realization of sign changing intensive plastic deformation when using “rhomb-square” system and alternating the rhomboid pass slope relative the roll axis is shown.
3. The computer simulation of the stressed and strained state of metal in the site of origin for strain during rolling in the rhomboid pass with non-diagonal location showed a high level of the shear strain intensity in comparison with rolling in the rhomboid pass with traditional diagonal location.
4. The laboratory experiment on “DUO-220” mill using a new rolling process realizing intensive plastic deformations showed the possibility of achieving high levels of mechanical properties in the minimum number of passes.
5. A new roll grooving for realization of the new rolling process as applied to the conditions of “320”bar mill of “Arselor Mittal Temirtau” JSC and designed sections of the working elements of guide fittings for the stands, where the new system of roll grooving will be used, has been developed.

REFERENCES