Development of a new progressive rolling technology of profile of neckless grooved tram rail

Bergeman G.V.

"EVRAZ – DMP nam. Petrovsky"

Abstract
In terms of rolling production of PJSC "EVRAZ – DMP nam. Petrovsky" there developed and introduced advanced technology of production of asymmetric rail profile of neckless grooved tram type. This profile is made on a rolling three-stand mill "800", which has linear arrangement of roughing and finishing two-roll stands and is used in the manufacture of modular construction of tramways in transport engineering.
Keywords: ASYMMETRIC PROFILE OF RAIL, THREE-STAND ROLLING MILL LINE "800", OPEN BOX GROOVE, COMB OF TOP AND BOTTOM STREAM GAUGE, HEAD, BOTTOM AND BEARING RIP OF TRAM RAIL.

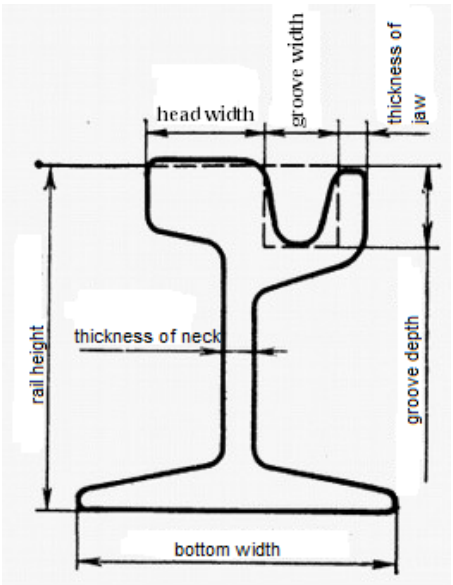
Problem statement

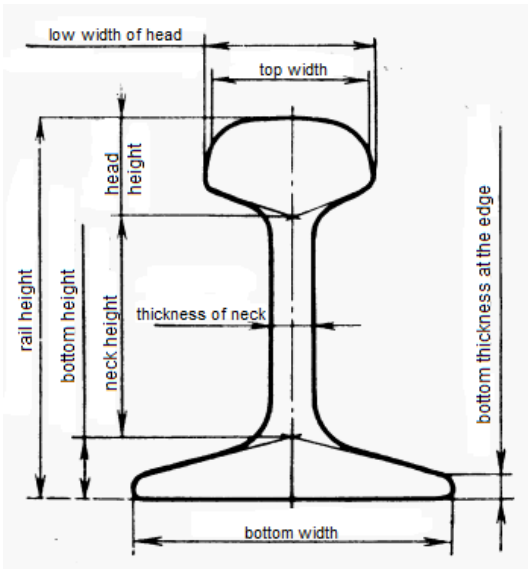
At the present time in Ukraine and SIS countries significant part of public transport facilities and costs falls on the city tram. Development of modern tram transport, which has positive ecological impact on city living space, primarily depends on the achievement of high indexes of transport capability of its rolling stock.

One of the key factors, positively affecting the solution of the question, is good technical condition of tram roads, which directly depend on the maintenance reliability (strength and longevity) of tram rails, in conjunction with more advanced and proving high resistance by means of their placing using non-sleeper technology.

During construction of tram roads in Ukraine and CIS countries, there mainly applied two main types of rails: tram grooved - $T_в65$, $T_в60$, T62, T58 types and standard rails of main-line railways - P65, P50 P43 types (fig.1). Classic profile of grooved tram rails (fig. 1-a) has its characteristic peculiarities – it is rather large, asymmetrical in two directions and has complicated configuration of cross section as compared with the profile of railroad rails (fig.1-b).

a)





b)

Figure 1. Main types of rails used during construction of tram rails in Ukraine and CIS countries and dimensions, which form their structural geometrical parameters.

Weight of 1 running meter of grooved tram rails being operated in Ukraine and CIS countries is given in the table 1.

Table 1.

Type of grooved tram rails	$T_в65$	$T_в60$,	T62	T58
Weight of 1 running meter of the rail (kg)	64.8	60.14	62.05	57.59

Composite structural elements of grooved tram rail are: deep groove, which separates head from the bearing rip (tips), which is being cut by vertical rolls in prefinishing and finishing passes of rolling mills, high and relavively thin neck and also wide bottom having thin ribs [1]. Besides, grooved tram rails differ from rail roads with chemical composition of structure steel (steel E75-E76) and the presence of thermal processing, due to which they are firm while statistical bending and also have high rates of hardness, durability and breaking strength. These qualitative characteristics speak for that grooved tram rails may be operated more intensive than rail road ones and bear significant dynamic loads [2].

At the beginning of 1980s to reduce constructional depth of superstructure of tram road during its construction and to reduce noise and vibrations arising while high-speed traffic of tram cars [3], there was developed special block non-sleeper travelling construction, more lasting and convenient during laying of tram track and its further maintenance as compared with the track placed according to traditional sleeper technology.

In this construction (fig.2), top structure of tram track is bearing ferroconcrete (rail) slab (panel) of large area, where “low” neckless tongue rails (TRNT) are placed of omega-type cress section [4-5].

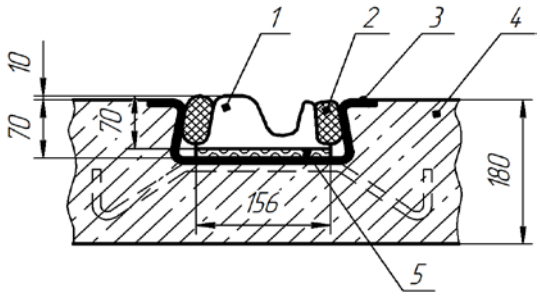


Figure 2. Block non-sleeper construction of tram road. neckless block groove rail; 2 – jointing rubber band; 3 – steel groove; 4 – bearing ferroconcrete slab; 5 – lining from rubber-cord composite.

Rails bear on the lining from rubber-cord composite by their bottom and with two side elastic rubber sealing strips are stiffly fixed in the special steel groove of ferroconcrete slab, herein the upper slab surface fulfills the function of road surfacing.

As compared with grooved tram rails $T_в65$, $T_в60$, and T62 with bottom width 180 mm, TRNT have more complicated configuration, smaller mass and smaller overall dimensions of cross section. So nominal overall dimensions of TRNT - 58 rails, which determine bottom width and height of this type of grooved tram track, are 156 and 70.8 mm.

At the present time this block non-sleeper construction of tram tracks with the usage of neckless grooved rails of TRNT-58 type, is actively used for laying new tram tracks and repairing of old ones and also widely used for support of their operable condition.

Main technical characteristics of rolled profile of neckless grooved tram rails of TRNT-58 type are given in the table 2.

Table 2. Technical characteristics of profile of neckless grooved tram rails of TRNT-58 type (according to TR U 27.1-053930565-257-2004)

Area of cross section of the rail (sm^2)	Theoretical mass of the 1st running meter of rail (kg)	Reference values for axis (x - x) and (y - y)					
		Moment of inertia J (sm^4)		Modulus of resistance W (sm^3)		Radius of inertia i	
S	m	J_x	J_y	W_x	W_y	i_x	i_y
74.54	58.52	288.96	1067.0	66.25	120.95	1.99	3.66

Main mechanical properties of rolled profile of neckless grooved tram rails of TRNT-58 type are given in the table 3.

Table 3. Mechanical properties of profile of neckless grooved tram rails of TRNT-58 type (according to TR U 27.1-053930565-257-2004)

Ultimate resistance G_u (n/mm^2) / (kgs/mm^2)	Yield point G_y (n/mm^2) / (kgs/mm^2)	Extension coefficient (δ)	Brinell hardness (HB)
not less than 785/80	not less than 390/40	not less than 5.0	not less than 218

According to tables 2-3 for this profile of tram rail it is characteristic high values of moment of inertia, tensile strength and stiffness and respectively significant torsional and space loads resistance, causing complex transverse-longitudinal bending.

Problem statement

Existing technological schemes of rolling and grooving of this asymmetric railway profile of TRNT tram track without neck, which has gained good reputation at Trshineckii metallurgical plant (Czech Republic) and at Novokuzneckii metallurgical plant (Russia), provide the usage for its production 7-9 trapezoidal and sectional (closed, semi-closed and open) grooves. However, despite the satisfactory quality of finished section TRNT and comparatively high productivity of rolling mills in the process of its manufacturing, these schemes of rolling and grooving have some significant disadvantages.

Negative aspect for trapezoidal grooves, which have big horizontal axis, is the fact that these grooves work unstable and require heightened attention to the adjustment, which after all is reflected on the reduction of productivity of rolling mill and degeneration of quality of forming TRNT profile. To the disadvantage of existing grooving used for production of TRNT profile, one may also refer the usage of great amount of enclosed-type grooves, which have gullies into the body of forming rolls, which significantly accelerates roll wear, complicates manufacturing of these grooves and also rolling in them breakdown bar of forming profile due to its active fixturing in closed grooves.

Besides, great amount of passes in the lines of rolling mills and also rather complicated configuration of TRNT profile leads to additional loss of temperature of breakdown bar of forming profile, contributes its accelerated cooling and respectively increased groove wear, which in its turn lead to reduction of hardness and forming roll braking and also metal losses in defective products due to unfinished section.

That is why development of new progressive rolling technology of asymmetric railroad profile of neckless grooved tram rail TRNT - 58 type due to creation in two-high mills of line rail-and-structural steel mill “800” of efficient system (definitive layout diagram) of rough and finishing mill group of grooves, which are meant for getting of stable and effective manufacturing of this rolled profile, and making an opportunity to increase significantly productivity of line rail-and-structural steel mill “800”, is current production problem.

Analysis of latest researches and publications

On reversing mill “950” of Trshineckii metallurgical plant, manufacturing of TRNT

profile starts with rolling of initial rectangular billet in the group of rough-edged closed trapezoidal grooves with further tilting for 90^0 of breakdown bar of forming profile, produced before its tracking into closed rough-edged sectional groove. Behavior in this groove of intensive direct draft along the height of framed trapezoidal breakdown bar allows starting gradual formation of components of structural elements of this asymmetric railway profile. Hereafter in alternating opened and closed rough-edged and finishing sectional grooves there occur successive and final forming of composite structural elements of profile cross section of non-necked grooved tram rail in the form of bottom, head, bearing rib (rubies) and flanged fixing elements [6].

On rail-and-structural steel mill 900 of Novokuzneckii metallurgical plant, during development of technology of production and grooving of rolls for manufacturing of neckless grooved tram rail, there used rolling scheme, according to which the formation of profile starts in symmetrical towards the vertical axis trapezoidal groove, formed in the upper and bottom parts according to passes of box grooves of greater and smaller width. Then breakdown bar is fed into inclined for $10 - 15^0$ with the diagonally opening, of nonequilateral trapeze type, semi-closed groove, formed by angled up and bottom passes, walls of which are fulfilled in a basad direction on the angles of 90^0 and $100 - 105^0$, where breakdown bar is being broken down along the height and one of the diagonals.

Hereafter breakdown bar after tilting for 90^0 is rolled in the system of closed and open sectional grooves with cycling along the height of grooves opening in side faces and with orientation of larger side of breakdown bar from nonequilateral trapezoidal grove sideward bearing rib (rubies) of the profile. Final formatting of the profile of neckless grooved tram rail is fulfilled in prefinishing and finishing grooves, having similar openings [7]. It should be marked that feature of construction present in rolling schemes and involved during production of asymmetrical railway profiles of neckless grooved tram rail type, are explained by the peculiarities of technological equipment of rolling mills and various engineer approaches to the solution of designing tasks of rolls grooving.

Results of performed work

Complex of rather labour consuming and near works preceded the achievement of stable industrial production of rolling profile of tram rail of grooved neckless TRNT – 58 type at Evraz Palini e Bertoli.

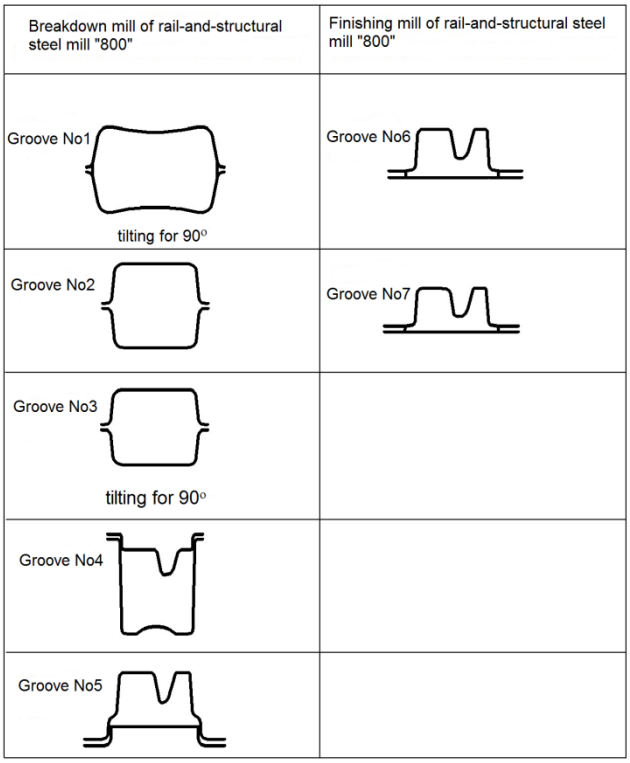


Figure 3. Structural scheme of arrangement and assembling of groups of rough-edged and finishing grooves of rail-and-structural steel mill “800”, involved for production of TRNT-58.

According to constructional peculiarities of this asymmetrical railway profile and technological possibilities of three-mill line rail-and-structural steel mill “800”, there was developed technological scheme of rolling and the groove designed for manufacturing of tram rail TRNT-58, roller guide is produced, complexes of production and test patterns and also there developed and confirmed technical standard documentation, which includes technical project on rolling of TRNT-58 profile and technical conditions on its manufacturing. On the basis of possibilities of technological equipment of mill “800” and TRNT-58 profile peculiarities, fulfilled grooving of rolls supposes its successive one-pass rolling in three open box passes and four sectional grooves (open and closed) with two tilting for 90^0 of breakdown bar of forming profile (fig. 3).

Incoming billet – bloom with square cross section, sizes 195x195 mm, smelted from steel grade K75 or K63F and formed in 5 grooves of blooming mill “1050” with heating temperature (1050^0C - 1110^0C) at the beginning is rolled in the

system of box and sectional grooves of breakdown mill of rail-and-structural steel mill “800”.

Structural scheme of location and assembly of the groups of roughing-out pass of the mill “800” primarily suggests successive one-pass rolling of breakdown bar of TRNT-58 forming profile in preparative rough-edged box grooves (open type) No1-No3, with further tilting for 90^0 of breakdown bar of forming profile before its tracking into the 2nd groove.

During deformation in the last open box pass No 3, breakdown bar of forming profile acquires rectangular shape and achieves overall geometrical dimensions 120 mm along the height and 142 mm along the width of groove. Further, after repeated titling for 90^o breakdown bar is fed into slotted rough-edged sectional groove (of closed type) No4 (fig.4) where by means of flanges of top and bottom pass grooves, in the body of breakdown bar there created groove 1 and riffle 2, forming main loops of composite elements of cross section of forming profile in the form of head 3, bearing ribs (rubies) 4 and flanges 5. Then breakdown bar of TRNT-58 forming profiles goes into profiling rough-edged sectional groove (closed type) No

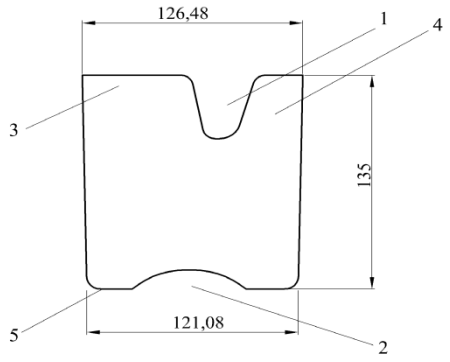


Figure 4. Cross section of TRNT-58 breakdown bar, being formed in rough-edged slitting pass No4.
1- groove; 2 — bottom; 3 — head; 4 — bearing rib (rubies); 5 - flanges

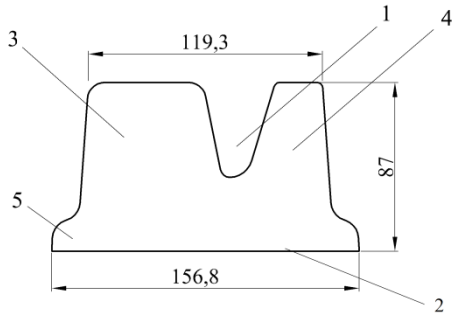


Figure 5. Cross section of TRNT-58 breakdown bar, being formed in rough-edged slitting pass No5.
1- groove; 2 — bottom; 3 — head; 4 — bearing rib (rubies); 5 - flanges

Herewith in this profiling sectional groove the formation of bottom end 2 only starts and formation of general configuration of composite elements of cross section of profile – groove 1, head 3, bearing rib (rubies) 4 and flanged fixing elements 5 actively continues. Final formation of geometrical dimensions of all components of structural elements of cross section of this asymmetrical railway profile, including the elements of bottom profile 6, there occur in the system of 2 open sectional groove formed by upper and lower rolls of finishing mill “800”. At the output of the finishing groove system, including the groove No 7, hot rolling of TRNT-58 profile with set geometry of elements of profile cross section, ends.

Further, cooled on mill “800” refrigerator, rolled TRNT-58 profile is surely subjected to cold straightening on special mangle, as in result of non-uniformity (differential) of cooling temperature of composite structural elements of TRNT-58 profile caused by their complex configuration and various sizes of area of cross section, rams of ready profile have departures from set curvature – both horizontal plane (not more than 0.08% of length of rail ram), and vertical plane (not more than 0.06% of length of rail ram).

During assimilation process, the most widespread surface defect in ready profile of neckless tram rail there was formation of ridge – tight walkway, located on the bottom end in the places of roll disconnect (fig.6), due to metal overtopping of prefinishing and finishing grooves and also camber of separate rams of ready profile because of deviation from set curvature in horizontal plane exceeding 0.08% of ram length.

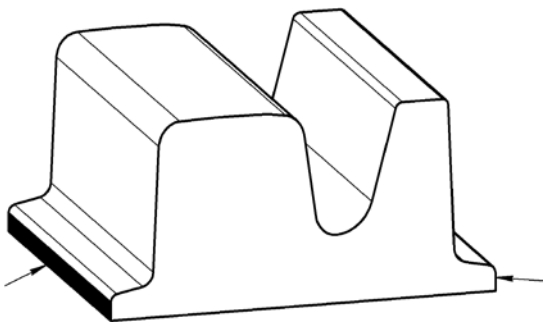
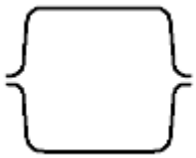
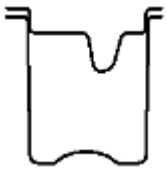
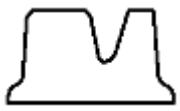
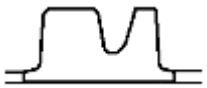
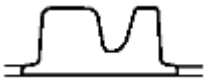


Figure 6. Place of formation of ridge (pointed with arrow) on the bottom edge of ready profile of neckless grooved tram rail TRNT-58.

Main performance characteristics describing suggested way of rolling of asymmetrical railway profile of neckless grooved tram rail TRNT-58 are given in the table 4.

Table 4.

General amount (number) of grooves (passes)	Configuration of groove form (incoming billet)	Area of cross section of groove (billet) S (sm^2)	Groove contraction of cross-sectional area ΔS (sm^2)	Groove contraction of cross-sectional area ΔS (%)	Reduction ratio obtained in this groove (λ)
0		(365.04)	-	-	-
1		258.04	107	29.3	1.415
2		191.88	66.16	25.64	1.345
3		172.49	19.39	10.1	1.112
4		150.49	22	12.75	1.146
5		100.82	49.67	33	1.493
6		85.31	15.51	15.38	1.182

7		76.04	9.27	10.86	1.122

According to table 4 , aggregate reduction ratio for TRNT-58 profile is: $(\lambda_{agg.}) = (\lambda_1) \times (\lambda_2) \times (\lambda_3) \times (\lambda_4) \times (\lambda_5) \times (\lambda_6) \times (\lambda_7) = 4.802$.

Conclusions

1. Given during rolling of asymmetric rail way profile of neckless grooved tram rail TRNT-58 overall dimensions of incoming billet, used for its manufacturing, groove form and construction, their amount and also structural scheme of their arrangement and assembly, in connection with obtained reduction ratio concerning separate grooves and aggregate coefficients of profile extension (λ) = 4.802, provide stable and effective manufacturing of tram rail TRNT-58 profile in conditions of rail and structural steel linear mill "800" with as low as practicable consumption of rolls, metal and gross energy.

2. Suggested in developed way of rolling of TRNT-58 variants of metal deformation in slotted and profiling sectional groove No4-No5, combined with general amount and structural fulfillment of group of rough-edged box grooves No1-No3 and group of finishing sectional grooves No6-No7 allow to create in the developed groove system optimal conditions in order to provide in grooves good stiffness of breakdown bars of TRNT-58 profile and also to increase productivity of rail and structural steel linear rolling mill "800" during "hot" time while its manufacturing.

3. Usage of temperature- speed rate of TRNT-58 profile rolling, obtained due to rational distribution of group of rough-edged and finishing grooves along the length of roll body in rough-edged and finishing stands of linear mill"800" and usage of as low as practicable number of passes while its manufacturing, allows to increase the temperature of rolling end and increase significantly hardness of prefinishing and finishing sectional grooves.

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