Simulation of Roll Passes For Section Rolling Of Flat-Footed Rail Section with the help of FEA

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Abstract - The rail sections are generally made of carbon steels by hot rolling process. The rolling of rail section is carried out in number of passes. For converting initial steel bloom into final rail section, the bloom is passed between numbers of rollers. Each roller has different grooves on it. The shape of groove decides the rolled section at each pass. So, to get desired section of each pass, we designed the sections which, in turn, reduce its cross-sectional area. The final finishing pass gives the standard rail section used in railways. Then the designed passes were simulated in Ansys workbench to determine induced stresses.

Keywords- hot rolling; steel; roll pass; rail section; FEM, Ansys workbench, Stress;

1. INTRODUCTION

The process of plastically deforming metal by passing it between rolls is known as *rolling*. It is most widely used metalworking process because it tends itself to high production rate and close control of the final product. In deforming metal between rolls, the work is subjected to high compressive stresses from the squeezing action of the rolls and to surface shear stresses as a result of the friction between the rolls and the metal. The friction forces are also responsible for drawing the metal into the rolls.

According to observation indicated by W. Zhang, C. Zhu and G. E. O. Widera, the rolling force and torque are the most important parameters influencing the determination of the energy for the rolling process [1]. Laila S. Bayoumi, concluded that Analysis of flow and stresses in isothermal steady-state round-oval-round pass sequence for the production of round bars has been obtained from a flowline field solution [2]. S.-H. Kim and Y. -T. Im investigated a knowledge-based expert system which was developed for the design of roll pass and profile sequences for the shape rolling of round and square bars [3]. Y. Lee, S. Choi and Y. H. Kim concluded that a reliable analytical model that determines the surface profile of a workpiece in round-oval-round pass sequence has been established [4]. Y. Lee and Y. H. Kim presented a semi-analytical method for the prediction of roll force in the oval-round pass rolling sequence [5]. A computer-aided-design (CAD) system to support roll pass design of bar rolling, where simple shapes like round and squares bars are produced, was developed in order to minimize trial and errors in industry by H. –C. Kwon and Y. –T. Im [6]. Stanislaw Turczyn, Andrzej Nowakowski and Miroslaw Michalowski developed a safe and reliable roll pass design for producing ribbed bars [7]. E. N. Chumachenko, I. V. Logashina, and S. A. Aksenov proposed that the three-dimensional problem of rolling in passes be simplified by solving it approximately by the finite element method [8]. Karen Abrinia and Alireza Fazlirad proposed to study external shape and calculate pressure and torque for the process of rolling shaped sections [9]. F. Lambiase and A. Langella developed an automatic roll pass design method, capable of minimizing the number of roll passes [10]. For rail rolling by universal mill, a simplified three-dimensional theoretical model was built firstly by DONG Yang-gang, ZHANG Wen-zhi and SONG lian-feng, [11].

In the literature reviewed above, roll pass designs of different sections researches are carried out like round, diamond, square sections etc. Moreover, the numerical simulation by FEM has been used in universal rolling process. Then, the theory of universal rolling method has been developed and improved. Although the universal rolling method has been applied in rail rolling for 30 years, there are only few theoretical researches about the rail rolling by universal mills. Since the process of rail universal rolling is very complex and the exact solution of force-energy parameter is difficult to be obtained, there is large a scope to work with the rail section. So, present work is aimed at roll pass design of section rolling of rail section.

2. STANDARD RAIL SECTIONS AND ITS SPECIFICATIONS

Rails are the members of the track laid in parallel lines to provide an unchanging, continuous, and level surface for the movement of trains. To be able to withstand stresses, they are made of carbon steel. The details for chemical composition and mechanical properties are given in Table 2.1.

Grade	C	Mn	Si	S (max.)	P (max.)	Al (max.)
880	0.6-0.8	0.8-1.3	1.3-0.5	0.035	0.035	0.02

Table 2.1 Chemical composition of steel for rails [13]

Rails are mainly of three types so far used. These are double headed rail, bull headed rail and flat-footed rail. The first rails used were double headed and made of an I or dumb-bell section. The idea was that once the head wore out during service, the rail could be inverted and used. Experience, however, showed that while in service the bottom table of the rail was dented to such an extent because of long and continuous contact with the chairs that it was not possible to reuse it. The problem faced with double headed rail led to the development of the bull headed rail, which had an almost similar shape but with more metal in the head to better withstand wear and tear. This rail section had the major drawback that chairs were required for fixing to the sleepers. A flat-footed rail is an inverted T-type section.

The rail is designated by its weight per unit length. In FPS units, it is the weight in lbs per yard and in metric units it is in kg per metre. A 52 kg/m rail denotes it has a weight of 52 kg per metre [13].

The standard rail sections in use in railways are 60 kg, 52kg, 90 R, 75 R, 60 R and 50 R. The two heavier rail sections, 60kg and 52kg, were recently introduced and are designated in metric units. Other rails are designated as per the revised British Standard specifications and are designated in FPS units though their dimensions and weight are in metric units. Mainly 60kg and 52kg are widely used in railways.

Rail section	Wt/m(kg)	Dimensions(mm)					
		A	B	C	D	E	F
52 kg	51.89	156	136	67	15.5	51	29
60 kg	60.34	172	150	74.3	16.5	51	31.5

Table 2.2 Details of standard rail sections [13]

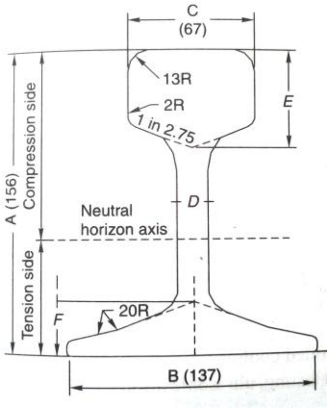

Figure 2.1 52-kg rail [13]

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3. ROLL PASS DESIGN FOR SECTION ROLLING OF FLAT-FOOTED RAIL SECTION

The standard rail section is generally made from steel blooms by hot rolling process. In rolling, the conversion of initial bloom to final section is achieved in number of passes. The number of passes generally depends on final section. The number of passes may be taken as 17 [14]. The initial bloom taken is having cross section of 390 mm x 285 mm and the final rail section is considered the 52 kg rail. F or maintaining smooth flow, the reduction in cross-sectional area is taken according to geometrical progression series. The designed exit sections at each roller pass are shown below.

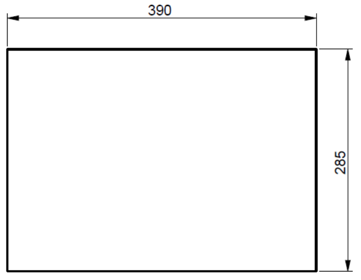

Figure 3.1 Initial steel bloom

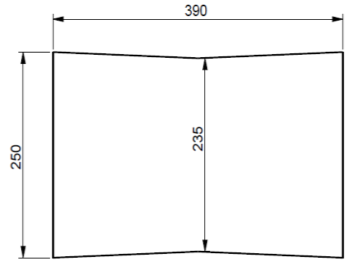

Figure 3.2 Section at pass–1

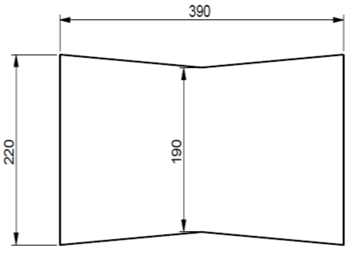

Figure 3.3 Section at pass–2

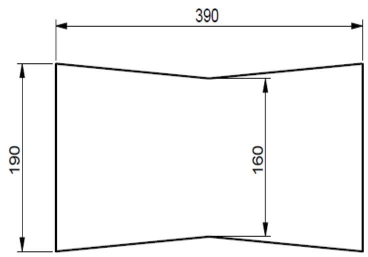

Figure 3.4 Section at pass–3

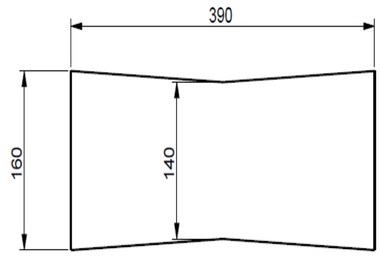

Figure 3.5 Section at pass–4

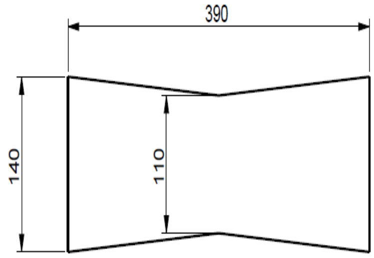

Figure 3.6 Section at pass–5

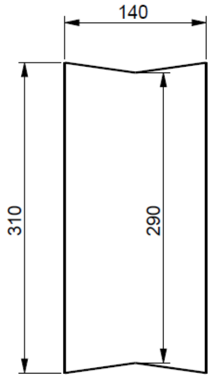

Figure 3.7 Section at pass–6

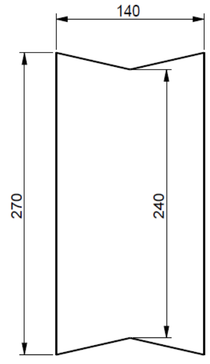

Figure 3.8 Section at pass–7

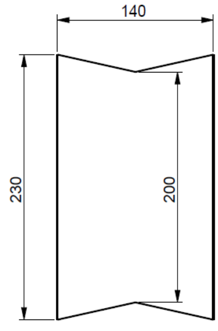

Figure 3.9 Section at pass-8

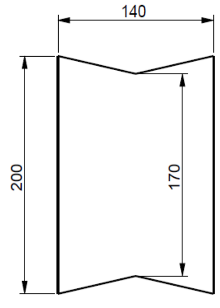

Figure 3.10 Section at pass-9

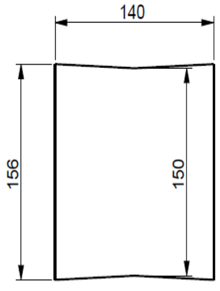

Figure 3.11 Section at pass-10

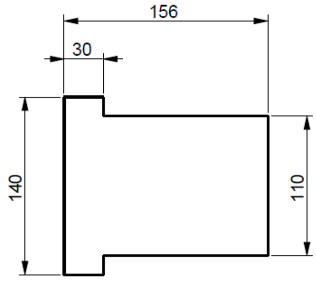

Figure 3.12 Section at pass-11

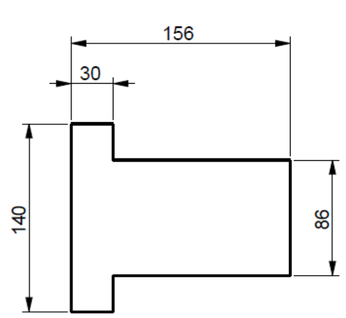

Figure 3.13 Section at pass–12

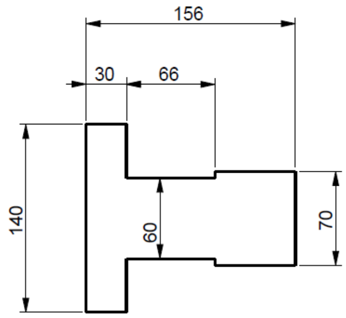

Figure 3.14 Section at pass–13

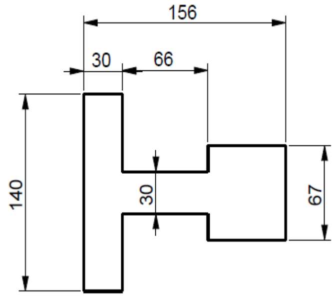

Figure 3.15 Section at pass– 14

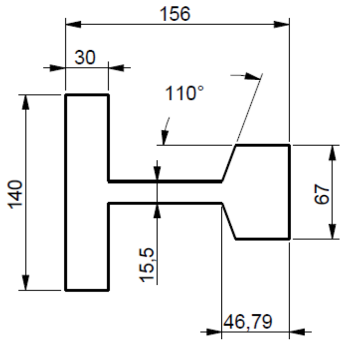

Figure 3.16 Section at pass-15

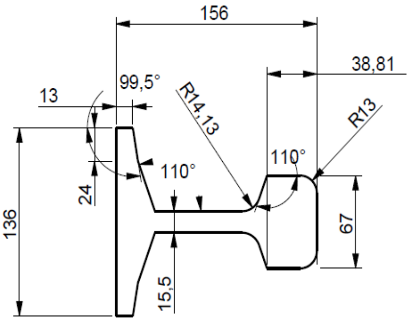

Figure 3.17 Section at pass–16

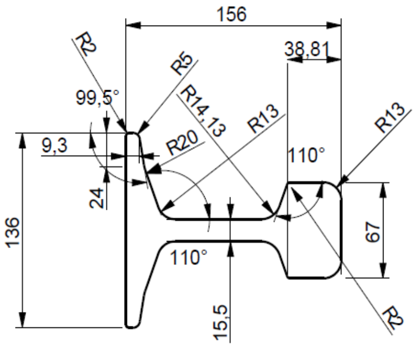

Figure 3.18 Section at pass–17

4. SIMULATION OF THE ROLL PASSES

All the passes shown above then simulated in Ansys workbench to determine the induced stresses during the rolling of the material. The set up of rolls and stands for the rolling stands is shown in below figure.

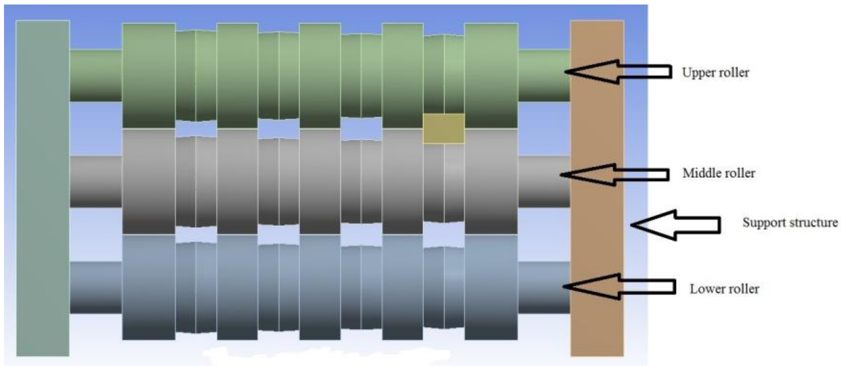

Figure 4.1 Rolling stand sample and its components

Coefficient of friction for the simulation is taken as 0.5. Other material properties used for the simulation are shown below.

	Roll stock material	Rolling and stands material
Material	Structural Steel	Titanium Alloy
Density (kg/m^3)	7850	4620
Specific Heat (J/kg.C)	434	522
Isotropic Elasticity		
Young's Modulus (GPa)	200	96
Poisson's ratio	0.3	0.36
Bulk modulus (GPa)	166.67	114.29
Shear modulus (GPa)	76.923	35.294
Bilinear Isotropic Hardening		
Yield strength (GPa)	0.25	0.93
Tangent modulus (GPa)	1.45	2.15

Table 4.1 Material properties used for simulation

5. RESULTS AND DISCUSSIONS

The simulated passes gave the stress values for each pass. The following table shows the results and other parameters considered during each roll passes.

Pass No.	Cross-sectional area (mm^2)	% reduction in area	Temp. of Material (°C)	Speed of rolls (rpm)	Velocity of material (m/s)	Angle of bite, α (°)	Stress (MPa)
1	94575	14.91	1150	60	1.0	22.78	1384.1
2	79950	15.46	1128	60	1.0	22.19	1187.2
3	68250	14.63	1107	60	1.0	21.79	1162.1
4	58500	14.29	1086	60	1.0	19.63	1162.8
5	48750	16.66	1066	30	1.2	19.30	1133.9
6	42000	13.84	1046	30	1.2	30.78	1183.0
7	35700	15.00	1027	30	1.2	24.78	1099.7
8	30100	15.69	1008	30	1.2	24.15	0935.4
9	25900	13.95	989	30	1.2	21.92	0801.2
10	21420	17.28	970	30	1.2	19.75	1062.9
11	18060	15.68	952	30	1.2	18.50	1073.5
12	15036	16.74	934	30	1.2	19.79	1775.6
13	12360	17.80	917	10	0.6	23.81	1810.2
14	10200	17.47	900	10	0.6	27.55	2457.5
15	8321.3	18.41	883	10	0.6	29.08	1926.2
16	7053.5	15.23	867	10	0.6	29.08	1407.9
17	6628.4	06.02	850	10	0.6	29.08	0807.9

Table 5.1 Results of simulation of each passes

Figure 5.1 and 5.2 show the graphs plotted for pass no. v/s % reduction in area and stress v/s angle of bite respectively.

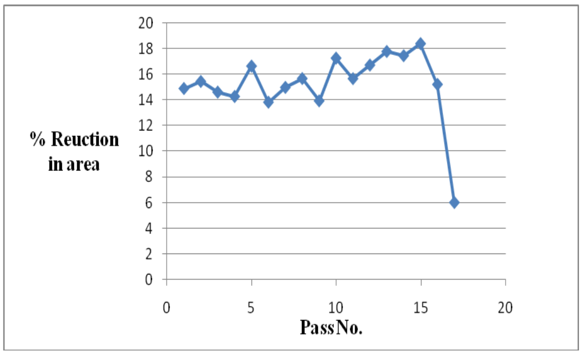

Figure 5.1 Pass No. v/s % reductions in area

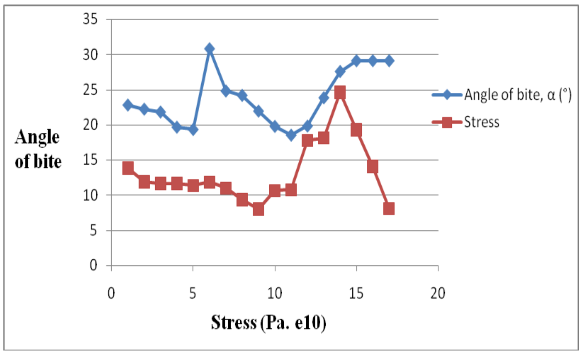

Figure 5.2 Stress v/s Angle of bite

From the above results & graphs, we may conclude as below:

- The % reduction in cross-sectional area in each pass is nearly uniform. To get fine finishing at the end, the reduction in final pass is low compare to previous passes.
- The stress induced in each pass varies according to the % reduction in area. It means the stress reduces as the % reduction in area reduces and vice versa, in most of the passes.
- The stress induced in each pass varies according to the angle of bite also. It means the stress reduces as the angle of bite reduces and vice versa, in most of the passes.
- From the above conclusions and results, we can say that the stress induced in each pass is above the material's flow stress and below the material's breaking stress.
- The abrupt reduction in cross-sectional area results in higher stress values during pass no. 12 to 16.

REFERENCES

[1] W. Zhang, C. Zhu and G. E. O. Widera, ON THE USE OF THE UPPER BOUND METHOD FOR LOAD DETERMINATION IN H-BEAM ROLLING. Journal of materials processing technology 56(1996) 820-833

[2] Laila S. Bayoumi, FLOW AND STRESSES IN ROUND-OVAL-ROUND ROLL PASS SEQUENCE. Int. J. Mech. Sci. Vol. 40, No. 12, pp. 1223-1234,1998

[3] S.-H. Kim, Y. -T. Im, A KNOWLEDGE-BASED EXPERT SYSTEM FOR ROLL PASS AND PROFILE DESIGN FOR SHAPE ROLLING OF ROUND AND SQUARE BARS. Journal of Materials Processing 89-90 (1999) 145-151

[4] Y. Lee, S. Choi, Y. H. Kim, MATHEMATICAL MODEL AND EXPERIMENTAL VALIDATION OF SURFACE PROFILE OF A WORKPIECE IN ROUND-OVAL-ROUND PASS SEQUENCE. Journal of materials processing technology 108 (2000) 87-96

[5] Y. Lee, Y. H. Kim, APPROXIMATE ANALYSIS OF ROLL FORCE IN A ROUND-OVAL-ROUND PASS ROLLING SEQUENCE. Journal of materials processing technology 113(2001) 124-130

[6] H. –C. Kwon, Y. –T. Im, INTERACTIVE COMPUTER-AIDED-DESIGN SYSTEM FOR ROLL PASS AND PROFILE DESIGN IN BAR ROLLING. Journal of materials processing technology 123(2002) 399-405

[7] Stanislaw Turczyn, Andrzej Nowakowski, Miroslaw Michalowski, ROLL PASS DESIGN FOR RIBBED BARS. Metal 2004

[8] E. N. Chumachenko, I. V. Logashina, and S. A. Aksenov, SIMULATION MODELLING OF ROLLING IN PASSES. Metallurgist, Vol. 50, Nos. 7-8, 2006

[9] Karen Abrinia, Alireza Fazlirad, THREE DIMENTIONAL ANALYSIS OF SHAPE ROLLINGUSING A GENERALLIZED UPPER BOUND APPROACH. Journal of Materials Processing Technology 209 (2009) 3264-3277

[10] F. Lambiase and A. Langella, AUTOMATED PROCEDURE FOR ROLL PASS DESIGN. ASM international, JMEPEG (2009) 18: 263-272

[11] DONG Yang-gang, ZHANG Wen-zhi, SONG lian-feng, Theoretical and Experimental Research on Rolling Force for Rail Hot Rolling by Universal Mill. Journal of iron and steel research, International. 2010, 17(1) : 27-32

[12] Dieter G. E., "Mechanical metallurgy", Tata McGraw-Hill Book Company, 1988, pp. 586-593.

[13] Chandra S., Agarwal M.M., "Railway engineering", Oxford university press, 2009, pp. 81-87.

[14] Roberts W. L., "Hot rolling of steel", Marcel Dekker Inc., 1983, pp. 367-376.