© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

A Study on Machining Time in Plunge Centerless Grinding

Do Duc Trung[1,*], Ngo Cuong[1], Nguyen Dinh Man[1],
Phan Bui Khoi[2], Pham Van Dong[3], Tran Quoc Hung[3]

[1]College of Economics and Technology, Thinh Dan, Thai Nguyen city, Viet Nam
[2]School of Mechanical Engineering, HUS, No. 1, Dai Co Viet, Ha Noi, Viet Nam
[3]Ha noi university of Industry, Ha Noi, Viet Nam
*Corresponding author: dotrung.th@gmail.com

ABSTRACT

This paper presents a study on machining time in plunge centerless grinding. The analysis on the relationship between machining time and geometrical parameters of technological system, kinematic parameter and grinding allowance, that shows the method to define the value of machining time in plunge centerless grinding process. Also, this paper given a equation of machining time, that shows the relationship between machining time and all above mentions.
Keywords: Plunge centerless grinding, geometric parameters, workpiece center displacement, grinding machine table displacement, machiing time.

I. INTRODUCTION

Centerless grinding is commonly employed for the mass production of rotationally symmetrical components, particularly in automotive industry with height productivity, set-up times are small compared to machining times. However, plunge centerless grinding is different other processes (turning, center grinding, ect). In plunge centerless grinding, the workpiece is located on the workpiece perimeter; the center height of workpiece that is not equal center height of wheels and it is moving in grinding time, ect. So machining time in plunge centerless grinding that is different with other processes. This paper presents a study on machining time in plunge centerless grinding. The analysis on the relationship between machining time (t_c) and geometrical parameters of technological system, kinematic parameter and grinding allowance, that shows the method to define the value of machining time in plunge centerless grinding process. Also, this paper given equation of t_c, that shows the relationship between machine – time and all above mentions.

II. METHODS AND MATERIAL

A. Kinetics Geometric Analysis of Workpiece

Plunge centerless grinding is a process where the axially symmetric workpiece lies in a defined stable position between a grinding wheel, a workrest blade and a regulating wheel which controls the workpiece speed (figure 1). In the majority of plunge centerless grinding applications, the regulating wheel - workpiece and workrest blade are fed towards the grinding wheel in horizontal direction with the feedrate S_k . Until grinding process is finished, grinding machine table displacement L_R , the radius of workpiece is reduced from R_{W1} to R_{W2} that make the workpiece center displaced from O_{W1} to O_{W2} . Consequently, workpiece center is displaced in the horizontal direction and vertical direction for Δx, Δy respectively.

Machining time in plunge centerless grinding t_c, that is calculated in below equation:

$$t_c = L_R / S_k \quad (1)$$

The ralationship between Δx, Δy with geometric parameters of technological system, which are presented by authors [1, 2] and Andrej MALIK, Augustin GOROG [3]:

$$L_R = \sqrt{\left(\frac{d_R}{2} + \frac{d_{R1}}{2}\right)^2 - h^2} - \sqrt{\left(\frac{d_R}{2} + \frac{d_{W1}}{2} - a\right)^2 - (h - \Delta y)^2} + \Delta x \quad (2)$$

$$\Delta y = \frac{a}{\cos\gamma} + \Delta x.tg\gamma \quad (3)$$

$$(tg^2\gamma + 1)\Delta^2 x + 2\left[\frac{t}{\cos\gamma}.tg\gamma - \sqrt{\left(\frac{d_G}{2} + \frac{d_{W1}}{2}\right)^2 - h^2} - h.tg\gamma\right]\Delta x + \frac{a^2}{\cos^2\gamma} - \frac{2.h.a}{\cos\gamma} = 0 \quad (4)$$

To survey equations (1), (2), (3), (4): machining time is depend on geometric parameters of technological system, grinding allowance, workpiece center height and feedrate. These equations is basis to get accuracy machining time in specific cases.

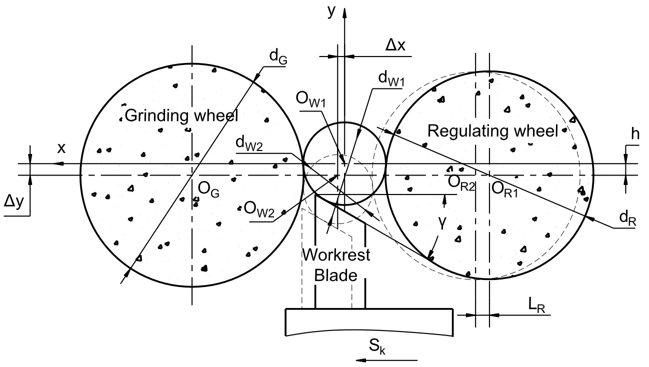

Figure 1. Plunge centerless grinding model

B. Machining Time Equation

To get machining time equation, it is necessary to get value of L_R in equations (2), (3), (4). To get L_R, value of input parameters are selected in below basis:

- Grinding wheel diameter and regulating wheel: $d_G = 200 \div 500(mm)$, $d_R = 200 - 500(mm)$.
- Workpiece diameter: $d_{W1} = 4 \div 80(mm)$.
- An approximate guide to workpiece center height is [4]:

$$h = \frac{1}{16}.\frac{1}{\frac{1}{d_G + d_{W1}} + \frac{1}{d_R + d_{W1}}} \quad (5)$$

So we get the range of workpiece center height: $h = 6,4 \div 18(mm)$.

- Grinding allowance: $a = 0,05 \div 0,15(mm)$
- Angle of workrest balde: $\gamma = 20 \div 40(^0)$.

Used calculation matrix with 2^k runs (k - number of input parameter). There are input parameters six, that includes: d_G , d_R , d_{W1} , h , a , γ ; Their value are showed in table 1.

III. RESULTS AND DISCUSSION

Table 1. Value of Input Parameters

Parameters	Symbol	Low level	Height level
Grinding wheel diameter (mm)	d_G	200	500
Regulating wheel diameter (mm)	d_R	200	500
Workpiece diameter (mm)	d_{W1}	4	80
Center height (mm)	h	6.4	18
Grinding allowance (mm)	a	0,05	0,15
Angle of workrest balde (^{0})	γ	20	40

Used software Minitab 16 to get matrix 2^k with six input parameters, the result is showed in table 2.

Table 2. Calculation Matrix

Runs	$d_G(mm)$	$d_R(mm)$	$d_{W1}(mm)$	$h(mm)$	$a(mm)$	$\gamma(^0)$
1	200	200	80	6.4	0.05	40
2	500	500	4	18	0.05	20
3	500	500	80	6.4	0.05	20
4	200	500	80	18	0.05	40
5	500	500	80	18	0.15	40
6	500	200	80	6.4	0.15	20
7	200	500	4	6.4	0.05	20
8	500	200	80	18	0.05	40
9	500	500	4	6.4	0.05	20
10	200	200	4	18	0.15	20
11	500	500	80	6.4	0.15	20
12	500	500	4	6.4	0.05	40
13	500	200	80	18	0.15	20
14	200	500	4	6.4	0.15	40
15	200	500	80	18	0.15	20
16	200	500	80	6.4	0.15	20
17	200	200	80	6.4	0.15	20
18	200	500	80	6.4	0.15	40
19	200	500	4	6.4	0.15	20
20	500	200	80	18	0.05	20
21	200	200	80	18	0.15	20
22	500	200	4	6.4	0.05	20
23	200	500	4	18	0.15	20
24	500	200	80	18	0.15	40
25	200	500	80	18	0.15	40
26	200	200	4	6.4	0.15	40
27	500	500	80	6.4	0.05	40
28	500	500	4	18	0.05	40
29	200	200	80	18	0.05	20
30	200	200	4	18	0.15	40
31	500	200	4	6.4	0.15	20
32	200	500	4	18	0.15	40
33	200	200	4	18	0.05	40
34	500	200	4	18	0.15	40
35	500	200	80	6.4	0.05	20
36	200	500	4	18	0.05	20
37	500	200	4	18	0.05	20
38	500	500	80	18	0.15	20
39	500	500	4	18	0.15	20
40	200	200	4	18	0.05	20
41	500	500	80	18	0.05	20
42	200	200	80	18	0.15	40
43	500	200	4	6.4	0.15	40
44	500	200	4	6.4	0.05	40
45	200	500	4	18	0.05	40
46	500	200	4	18	0.05	40
47	500	200	80	6.4	0.05	40
48	200	500	80	6.4	0.05	20
49	500	500	4	18	0.15	40
50	200	200	80	6.4	0.15	40

51	200	200	80	18	0.05	40
52	200	500	80	18	0.05	20
53	500	200	80	6.4	0.15	40
54	500	500	80	6.4	0.15	40
55	200	500	80	6.4	0.05	40
56	200	200	4	6.4	0.15	20
57	500	200	4	18	0.15	20
58	200	200	4	6.4	0.05	20
59	500	500	4	6.4	0.15	20
60	200	200	80	6.4	0.05	20
61	200	500	4	6.4	0.05	40
62	500	500	4	6.4	0.15	40
63	200	200	4	6.4	0.05	40
64	500	500	80	18	0.05	40

Used equations (2), (3), (4) to get values of L_R with varied value of d_G, d_R, d_{W1}, h, a, γ in table 2, the result is showed in table 3.

Table 3. Result matrix

Runs	$d_G(mm)$	$d_R(mm)$	$d_{W1}(mm)$	$h(mm)$	$a(mm)$	$\gamma(^0)$	L_R	L_R^*
1	200	200	80	6.4	0.05	40	0.0586	0.0631
2	500	500	4	18	0.05	20	0.0502	0.0508
3	500	500	80	6.4	0.05	20	0.0504	0.0452
4	200	500	80	18	0.05	40	0.0716	0.0720
5	500	500	80	18	0.15	40	0.1832	0.1908
6	500	200	80	6.4	0.15	20	0.1432	0.1334
7	200	500	4	6.4	0.05	20	0.0541	0.0513
8	500	200	80	18	0.05	40	0.0668	0.0625
9	500	500	4	6.4	0.05	20	0.0500	0.0452
10	200	200	4	18	0.15	20	0.1533	0.1699
11	500	500	80	6.4	0.15	20	0.1511	0.1356
12	500	500	4	6.4	0.05	40	0.0540	0.0567
13	500	200	80	18	0.15	20	0.1329	0.1497
14	200	500	4	6.4	0.15	40	0.1722	0.1928
15	200	500	80	18	0.15	20	0.1787	0.1725
16	200	500	80	6.4	0.15	20	0.1619	0.1536
17	200	200	80	6.4	0.15	20	0.1545	0.1511
18	200	500	80	6.4	0.15	40	0.1701	0.1925
19	200	500	4	6.4	0.15	20	0.1622	0.1539
20	500	200	80	18	0.05	20	0.0443	0.0499
21	200	200	80	18	0.15	20	0.1618	0.1697
22	500	200	4	6.4	0.05	20	0.0458	0.0445
23	200	500	4	18	0.15	20	0.1793	0.1728
24	500	200	80	18	0.15	40	0.2008	0.1877
25	200	500	80	18	0.15	40	0.2152	0.2162
26	200	200	4	6.4	0.15	40	0.1817	0.1897
27	500	500	80	6.4	0.05	40	0.0537	0.0566
28	500	500	4	18	0.05	40	0.0619	0.0636
29	200	200	80	18	0.05	20	0.0539	0.0565
30	200	200	4	18	0.15	40	0.2559	0.2130
31	500	200	4	6.4	0.15	20	0.1376	0.1336
32	200	500	4	18	0.15	40	0.2231	0.2165

33	200	200	4	18	0.05	40	0.0851	0.0709
34	500	200	4	18	0.15	40	0.2144	0.1879
35	500	200	80	6.4	0.05	20	0.0477	0.0444
36	200	500	4	18	0.05	20	0.0598	0.0575
37	500	200	4	18	0.05	20	0.0395	0.0500
38	500	500	80	18	0.15	20	0.1531	0.1522
39	500	500	4	18	0.15	20	0.1506	0.1525
40	200	200	4	18	0.05	20	0.0511	0.0566
41	500	500	80	18	0.05	20	0.0511	0.0507
42	200	200	80	18	0.15	40	0.2351	0.2127
43	500	200	4	6.4	0.15	40	0.1712	0.1674
44	500	200	4	6.4	0.05	40	0.0570	0.0557
45	200	500	4	18	0.05	40	0.0742	0.0721
46	500	200	4	18	0.05	40	0.0714	0.0626
47	500	200	80	6.4	0.05	40	0.0556	0.0557
48	200	500	80	6.4	0.05	20	0.0540	0.0512
49	500	500	4	18	0.15	40	0.1858	0.1911
50	200	200	80	6.4	0.15	40	0.1761	0.1894
51	200	200	80	18	0.05	40	0.0782	0.0708
52	200	500	80	18	0.05	20	0.0596	0.0575
53	500	200	80	6.4	0.15	40	0.1669	0.1671
54	500	500	80	6.4	0.15	40	0.1612	0.1699
55	200	500	80	6.4	0.05	40	0.0566	0.0641
56	200	200	4	6.4	0.15	20	0.1507	0.1514
57	500	200	4	18	0.15	20	0.1187	0.1500
58	200	200	4	6.4	0.05	20	0.0502	0.0504
59	500	500	4	6.4	0.15	20	0.1501	0.1358
60	200	200	80	6.4	0.05	20	0.0515	0.0503
61	200	500	4	6.4	0.05	40	0.0573	0.0642
62	500	500	4	6.4	0.15	40	0.1621	0.1702
63	200	200	4	6.4	0.05	40	0.0604	0.0632
64	500	500	80	18	0.05	40	0.0610	0.0635

Change the form of result matrix (in Table 3) in to logarithm form, the result is show in Table 4.

Table 4. Logarithm matrix

Runs	$\mathrm{Log}(d_G)$	$\mathrm{Log}(d_R)$	$Log(d_{W1})$	$Log(h)$	$Log(a)$	$Log(\gamma)$	$Log(L_R)$
1	2.3010	2.3010	1.9031	0.8062	-1.3010	1.6021	-1.2323
2	2.6990	2.6990	0.6021	1.2553	-1.3010	1.3010	-1.2994
3	2.6990	2.6990	1.9031	0.8062	-1.3010	1.3010	-1.2977
4	2.3010	2.6990	1.9031	1.2553	-1.3010	1.6021	-1.1451
5	2.6990	2.6990	1.9031	1.2553	-0.8239	1.6021	-0.7372
6	2.6990	2.3010	1.9031	0.8062	-0.8239	1.3010	-0.8441
7	2.3010	2.6990	0.6021	0.8062	-1.3010	1.3010	-1.2665
8	2.6990	2.3010	1.9031	1.2553	-1.3010	1.6021	-1.1750
9	2.6990	2.6990	0.6021	0.8062	-1.3010	1.3010	-1.3007
10	2.3010	2.3010	0.6021	1.2553	-0.8239	1.3010	-0.8145
11	2.6990	2.6990	1.9031	0.8062	-0.8239	1.3010	-0.8207
12	2.6990	2.6990	0.6021	0.8062	-1.3010	1.6021	-1.2678
13	2.6990	2.3010	1.9031	1.2553	-0.8239	1.3010	-0.8766
14	2.3010	2.6990	0.6021	0.8062	-0.8239	1.6021	-0.7640
15	2.3010	2.6990	1.9031	1.2553	-0.8239	1.3010	-0.7478
16	2.3010	2.6990	1.9031	0.8062	-0.8239	1.3010	-0.7907
17	2.3010	2.3010	1.9031	0.8062	-0.8239	1.3010	-0.8111

18	2.3010	2.6990	1.9031	0.8062	-0.8239	1.6021	-0.7693
19	2.3010	2.6990	0.6021	0.8062	-0.8239	1.3010	-0.7899
20	2.6990	2.3010	1.9031	1.2553	-1.3010	1.3010	-1.3540
21	2.3010	2.3010	1.9031	1.2553	-0.8239	1.3010	-0.7911
22	2.6990	2.3010	0.6021	0.8062	-1.3010	1.3010	-1.3390
23	2.3010	2.6990	0.6021	1.2553	-0.8239	1.3010	-0.7465
24	2.6990	2.3010	1.9031	1.2553	-0.8239	1.6021	-0.6973
25	2.3010	2.6990	1.9031	1.2553	-0.8239	1.6021	-0.6671
26	2.3010	2.3010	0.6021	0.8062	-0.8239	1.6021	-0.7406
27	2.6990	2.6990	1.9031	0.8062	-1.3010	1.6021	-1.2701
28	2.6990	2.6990	0.6021	1.2553	-1.3010	1.6021	-1.2084
29	2.3010	2.3010	1.9031	1.2553	-1.3010	1.3010	-1.2680
30	2.3010	2.3010	0.6021	1.2553	-0.8239	1.6021	-0.5919
31	2.6990	2.3010	0.6021	0.8062	-0.8239	1.3010	-0.8612
32	2.3010	2.6990	0.6021	1.2553	-0.8239	1.6021	-0.6515
33	2.3010	2.3010	0.6021	1.2553	-1.3010	1.6021	-1.0703
34	2.6990	2.3010	0.6021	1.2553	-0.8239	1.6021	-0.6687
35	2.6990	2.3010	1.9031	0.8062	-1.3010	1.3010	-1.3215
36	2.3010	2.6990	0.6021	1.2553	-1.3010	1.3010	-1.2234
37	2.6990	2.3010	0.6021	1.2553	-1.3010	1.3010	-1.4032
38	2.6990	2.6990	1.9031	1.2553	-0.8239	1.3010	-0.8149
39	2.6990	2.6990	0.6021	1.2553	-0.8239	1.3010	-0.8223
40	2.3010	2.3010	0.6021	1.2553	-1.3010	1.3010	-1.2915
41	2.6990	2.6990	1.9031	1.2553	-1.3010	1.3010	-1.2920
42	2.3010	2.3010	1.9031	1.2553	-0.8239	1.6021	-0.6287
43	2.6990	2.3010	0.6021	0.8062	-0.8239	1.6021	-0.7665
44	2.6990	2.3010	0.6021	0.8062	-1.3010	1.6021	-1.2443
45	2.3010	2.6990	0.6021	1.2553	-1.3010	1.6021	-1.1296
46	2.6990	2.3010	0.6021	1.2553	-1.3010	1.6021	-1.1465
47	2.6990	2.3010	1.9031	0.8062	-1.3010	1.6021	-1.2552
48	2.3010	2.6990	1.9031	0.8062	-1.3010	1.3010	-1.2674
49	2.6990	2.6990	0.6021	1.2553	-0.8239	1.6021	-0.7309
50	2.3010	2.3010	1.9031	0.8062	-0.8239	1.6021	-0.7544
51	2.3010	2.3010	1.9031	1.2553	-1.3010	1.6021	-1.1069
52	2.3010	2.6990	1.9031	1.2553	-1.3010	1.3010	-1.2247
53	2.6990	2.3010	1.9031	0.8062	-0.8239	1.6021	-0.7775
54	2.6990	2.6990	1.9031	0.8062	-0.8239	1.6021	-0.7926
55	2.3010	2.6990	1.9031	0.8062	-1.3010	1.6021	-1.2471
56	2.3010	2.3010	0.6021	0.8062	-0.8239	1.3010	-0.8220
57	2.6990	2.3010	0.6021	1.2553	-0.8239	1.3010	-0.9256
58	2.3010	2.3010	0.6021	0.8062	-1.3010	1.3010	-1.2991
59	2.6990	2.6990	0.6021	0.8062	-0.8239	1.3010	-0.8236
60	2.3010	2.3010	1.9031	0.8062	-1.3010	1.3010	-1.2880
61	2.3010	2.6990	0.6021	0.8062	-1.3010	1.6021	-1.2419
62	2.6990	2.6990	0.6021	0.8062	-0.8239	1.6021	-0.7903
63	2.3010	2.3010	0.6021	0.8062	-1.3010	1.6021	-1.2188
64	2.6990	2.6990	1.9031	1.2553	-1.3010	1.6021	-1.2147

Used Tool/ Data Analysis function in Excel to analysed table 4, the result is show in table 5.

Table 5. Result analysis

Parameters	***Coefficients***	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	-0.23654	0.1037	-2.2817	0.0263	-0.4441	-0.0289	-0.4441	-0.0289

$Log(d_G)$	-0.13647	0.0244	-5.5830	0.0000	-0.1854	-0.0875	-0.1854	-0.0875
$Log(d_R)$	0.01802	0.0244	0.7373	0.4639	-0.0309	0.0670	-0.0309	0.0670
$Log(d_{W1})$	-0.00049	0.0075	-0.0653	0.9481	-0.0155	0.0145	-0.0155	0.0145
$Log(h)$	0.11205	0.0217	5.1734	0.0000	0.0687	0.1554	0.0687	0.1554
$Log(a)$	1.00072	0.0204	49.0859	0.0000	0.9599	1.0415	0.9599	1.0415
$Log(\gamma)$	0.32555	0.0323	10.0749	0.0000	0.2608	0.3903	0.2608	0.3903

To survey table 5: d_G, h, a, γ that have significant influence on L_R, so they have significant influence on t_c

Also, in table 5, we get:

$$log(L_R) = -0,23654 - 0,13647.\log(d_G) + 0,01802.\log(d_R) - 0,00049.\log(d_{W1}) + 0,11205.\log(h) + 1,00072.\log(a) + 0,32555.\log(\gamma) \quad (6)$$

To changed equation (6), we get:

$$L_R = 0,58.d_G^{-0,13647}.d_R^{0,01802}.d_{W1}^{-0,00049}.h^{0,11205}.a^{1,00072}.\gamma^{0,32555} \quad (7)$$

The upper model can be used to predict grinding machine table displacement at particular design points. The numerical values of grinding machine table displacement L_R^* and L_R are also summarized in Table 3. The differences between the caculation and predicted responses are shown in Figure 2.

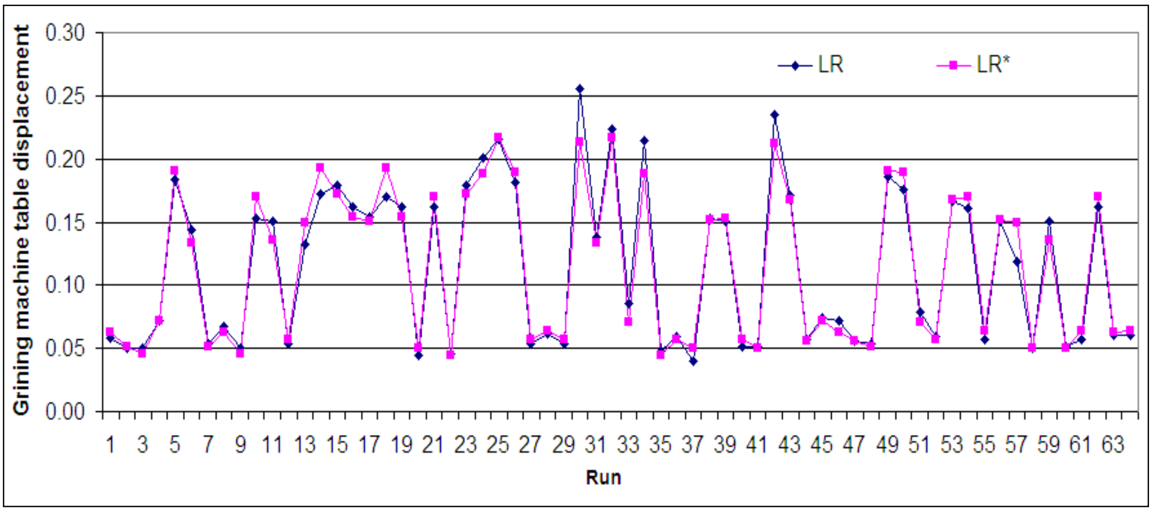

Figure 2. Grinding machine table displacement L_R^* and L_R

To survey Figure 6: values of L_R^* are very near values of L_R. So, equation to get machining time t_c:

$$t_c = \frac{1}{S_k}.0,58.d_G^{-0,13647}.d_R^{0,01802}.d_{W1}^{-0,00049}.h^{0,11205}.a^{1,00072}.\gamma^{0,32555} \quad (8)$$

Equation (8) that described the relationship between machining time and feedrate, grinding wheel diameter, regulating wheel diameter, workpiece diameter, workpiece center height, Grinding allowance and angle of workrest balde.

IV. CONCLUSION

An analytical was developed for the relationship between machining time and feedrate, grinding wheel diameter, regulating wheel diameter, workpiece diameter, workpiece center height, grinding allowance and angle of workrest balde. That is tool to get accurate value of machining time.

- Given an equation to get machining time in specific cases.

V. REFERENCES

[1] Do Duc Trung, Influence of technology parameters on workpiece centre dispacement in plunge centerless grinding, Processding of 2th young scicencific conference, Thai Nguyen university, 67 – 71, (2014).

[2] Do Duc Trung, Tran Minh Truong, Pham Van Dong, Nguyen Xuan Dinh, Relationship between grinding machine table displacement and geometriccal parameters of technolocial system in plunge centerless grinding, Journal of science and technology, Ha Noi universty of industry, No 29, 26-28 (2015).

[3] Andrej MALIK, Augustin GOROG, Process centerless recess grinding, Faculty of materials science and technology in trnaya, Slovak University of technology in Bratislava (2010).

[4] Loan D. Marinescu, Mike Hitchiner, Eckart Uhlmann and W. Brian Rowe, Handbook of machining with grinding wheels, CRC Press Taylor & Francis Group (2006).