Burr Edge Occupancy: An Edge Finishing Index for Milling Machined Parts

Journal:	<i>Transactions of the Canadian Society for Mechanical Engineering</i>
Manuscript ID	TCSME-2018-0066.R1
Manuscript Type:	Article
Date Submitted by the Author:	05-Jun-2018
Complete List of Authors:	Niknam, Seyed Ali; Iran University of Science and Technology, School of Mechanical Engineering; Ecole Polytechnique de Montreal, Mechanical Engineering Tiabi, Azziz; Ecole de technologie superieure, Mechanical Engineering Songmene, Victor; Ecole de technologie superieure, Mechanical Engineering
Keywords:	Burr, Deburring, Edge finishing, Machining, Slot Milling
Is the invited manuscript for consideration in a Special Issue? :	Not applicable (regular submission)

SCHOLARONE™
Manuscripts

Burr Edge Occupancy: An Edge Finishing Index for Milling Machined Parts

Seyed Ali Niknam^{1*}, Azziz Tiabi², Victor Songmene²

¹Sustainable Manufacturing Systems Research Laboratory, School of Mechanical Engineering, Iran
University of Science and Technology, Tehran, Iran; saniknam@iust.ac.ir

²Mechanical Engineering Department, École de Technologie Supérieure, Montréal, Canada.
azziz.tiabi.1@ens.etsmtl.ca ; victor.songmene@etsmtl.ca

*Corresponding author

Abstract

Machining burrs are formed wherever is an edge. One of the useful solutions to decrease the machining time and cost, in particular when dealing with milling parts is to generate the machined parts edges with minimum burr. To this end, this article proposes burr edge occupancy η_s as an index to evaluate the deburring difficulty and consequently adequate selection of suitable deburring methods. Therefore, it is initially required to evaluate the sensitivity of η_s to cutting parameters. To that end, the main governing factors on η_s were investigated when slot milling two types of aluminium alloys in the automotive and aerospace industries that belong to different families. The cutting parameters that led to edges with minimum η_s were presented. It was found that unlike the most of the burr size attributes, the η_s is sensitive to the variation of cutting parameters used, in principle cutting speed, family of material and cutting tools. In fact, lower η_s means less time and efforts for deburring and edge finishing of machined parts. Furthermore, this should be underlined that η_s measurement is more convenient than the procedures used to measure other burr size attributes, including burr height (b_h) and burr thickness (b_t).

Keywords: Burr, Deburring, Edge finishing, Machining, Slot Milling.

Draft

Introduction

Due to global competition, the machinability attributes such as tool life, chip characteristics, chip disposal, surface finish and burr formation are of major concern when dealing with high precision machining (Niknam et al. 2014a). The presence of the latter tend to affects the work part quality and precise accuracy of the deburring processes (Songmene et al. 2013; Niknam et al. 2014b). Up until now, the machinability attributes of several easy to difficult to cut materials, in particular, burr formation mechanism and morphology in brittle and ductile materials are very well understood, and sophisticated approaches for adequate prevention and minimization were introduced (Chen et al. 2006; Niknam et al. 2012; Gillespie et al. 1976; Nakayama et al. 1987; Ko et al.1991; Dornfeld et al.2004; Lauderbaugh 2009; Lekkala et al. 2011; Niknam et al. 2014c). However, it is to note that the aforementioned approaches are however mostly limited to material and operational conditions used. Knowing that over 100 deburring processes were proposed so far (Gillespie 1999) , comprehensive investigations on factors governing deburring selection which in fact tend to minimize the non-desirable expenses are strongly advised. Among machining operations, milling burr formation morphology is very complex. However, fundamental aspects of burr formation, as well as milling burr size minimization have been reasonably understood (Hashimura et al. 1995; Olvera et al. 1996; Lin 2000; Chern 2006; Biermann et al. 2010; Niknam et al. 2013a) and several solutions including experimental characterization and analytical modeling approaches were presented (Aurich et . 2009; Niknam et al. 2014a; Niknam et al. 2015. However, among milling operations, slot milling (Figure 1) has a very complex burr shape and formation mechanism which may pose complex difficulties during deburring operations (Niknam 2013; Niknam et al. 2014d). In fact, slot milling burrs could be large or small, even not visible with naked eyes (Figure 2). It is therefore recommended to limit and control the burr size and morphology, otherwise secondary operations so- called as deburring which are time-consuming and expensive are needed. Unfortunately, except limited studies which were

mostly conducted by the authors (Niknam et al. 2013a; Tiabi 2010; Niknam et al. 2013b) and (Luo et al. 2008), low amount of information is available about the factors governing slot milling burrs.

In fact, to gain an adequate burr description, a new term, called “burr value”, comprises several burr size attributes (Figure 3) was proposed (Schäfer 1975). As noted in (Rangarjan 2005), the most widely used burr size attributes are burr height (b_h) and thickness (b_t) which in principle are widely used for tool replacement, schedule arrangement, and evaluation of the burr removal difficulties. According to (Niknam et al. 2013c), the longitudinal profile of the burr is not commonly used to define the burrs as it is not highly informative in most cases. Instead, the burr thickness (b_t) is frequently used to determine deburring time and methods (Aurich et al. 2009; Niknam et al. 2014a). However, as noted in numerous studies (Niknam et al. 2013; Niknam et al. 2014; Niknam et al. 2014; Niknam et al. 2015; Niknam et al. 2017), due to complex interactions between cutting process parameters, a direct relationship can not be formulated between cutting parameters and burr size attributes. Furthermore, adequate measurement of the burr thickness is considered as a time-consuming approach which requires high resolutions cameras and SEM machines. This, in fact, poses significant difficulties when predictive modeling of burr size attributes are demanded (Niknam et al. 2013b; Iwata et al. 1984; Kloeche et al. 2004; Leopold et al. 2010; Lekkala et al. 2011; Niknam 2013). According to (Narayanaswami et al. 1994), the burr location and length, work part edges as well as material to be deburred are other critical factors on deburring complexity (Gillespie 1999). However, In order to investigate the adequate solutions to achieve edges with minimum burrs, an innovative index, so-called burr edge occupancy η_s (Eq.1) is proposed in this work, which not only incorporates the effects of critical factors on deburring selection, but also, it does not require the time-consuming burr size measurement tasks.

Theoretical Base

As noted in (Niknam et al. 2014d), only five slot milling burrs (Figure 1) are visible with naked eyes. Even though, adequate measurement of the burr size attributes (b_t , b_h), associated to each slot milling burr (Figure 1) is complex and time-consuming. To remedy the lack of knowledge aforementioned, the burr edge occupancy η_s is proposed as an innovate parameter which can be used for precise selection of deburring operations, incorporating the presence of all burrs. As shown in Eq.1, η_s represents a percentage of the edges occupied by the burrs (Figure 4) as follows:

$$\eta_s = \frac{\sum_{i=1}^6 l_i}{\sum_{i=1}^6 L_i} \times 100 \quad (1)$$

Where:

l_i : represents the length of burrs occupation on the edge i

L_i : represents the length of edge number i

The burr edge occupancy η_s in Eq.1 covers six edges in milled slot parts. To attribute value to l_i , burrs should have at least a minimum height of 0.1 mm. The logic behind burr edge occupancy η_s denotes that higher η_s means more efforts demanded to browse the machined part edges towards adequate burr removal and edge finishing. In fact, lower η_s means less time and efforts for deburring and edge finishing of machined parts. It should be underlined that burr edge occupancy η_s measurement is more convenient than the procedures used to measure other burr size attributes, including burr height b_h and burr thickness b_t . It can be considered as the main potential elements, encouraging further investigations on this subject. To that end, the following experimental tests were conducted to

evaluate the factors governing η_s . In fact, higher sensitivity of η_s to the variation of cutting parameters reflects the adequacy of the proposed index in Eq.(1).

Experimental plan

As shown in Table 1, the multi-level full factorial design of experiment was used in this work, and dry slot milling tests were conducted on AA 2024-T351 and AA 7075-T6 work parts using a 3-axis CNC machine and a carbide cutting tool (D=19.05 mm) under dry condition. The overview of the mechanical properties of the tested work parts is presented in Table 2. The experimental works consisted of five controllable cutting parameters as listed in Table 1. The experimental works were repeated twice, and the average values of responses were considered for analysis. In total, 324 milling tests were necessary to complete the study. A 3-axis CNC machine tool (Power: 50kW, maximum speed: 28000 rpm; Torque: 50 Nm) was used in milling tests (Figure 5a). A slot milling tool with three flutes $Z=3$ and tool diameter D 19.05mm were used (Figure 5b).

Result and discussion

Method of analysis

Statistical tools such as Pareto chart and surface response models were used to investigate the factors governing burr edge occupancy η_s when slot milling 7075-T6 and 2024-T351 aluminium alloys. The overview of statistical methods used is presented in (Niknam et al. 2013d). Among empirical modeling approaches, the multiplicative model was used.

Results

The first considerations of the burr formation refer back to chip formation, as the burr formation mechanism is highly affected by chip formation mechanism. It is agreed upon that feed rate, depth of

cut, cutting speed and tool geometry are the main controlling parameters on milling burr formation morphology and size (Korkut et al. 2007). In fact, burr size minimization can be conducted by using adequate strategies leading to the transition of primary burrs to secondary burrs (Niknam 2017). It is therefore required to identify the factors governing burr formation according to the type of material and machining operation used. To that end, statistical tools as aforementioned were used. Pareto charts and the main effect plot of η_s are shown in Figure 6. It can be underlined that cutting tool (A), cutting speed (E), material (A), depth of cut (C) and feed per tooth (D) are the leading direct factors affecting η_s . Knowing that the tested materials are from different families, the statistical significance could be attributed to mechanical properties of the tested materials, such as ductility and brittleness which may pose variation in burr formation shapes and mechanism. As shown in Figure 6, higher levels of cutting speed, feed per tooth and depth of cut led to increased η_s . This denotes more required efforts for deburring and edge finishing. As shown in Figure 6, under the similar cutting condition, the higher resulting value of η_s is observed in AA7075-T6 (Fig.7 and Table 1) which is, however, harder than AA 2024-T351 (Tiabi 2010).

As noted in (Niknam et al. 2013), under similar cutting conditions as presented in this work, exit, top and entrance burrs are governed by different cutting parameters. This phenomenon can be related to material properties, burr formation mechanism, as well as the tool geometry and coating used. In fact, when cutting tools with multiple teethes are used, heat generation increases, in particular in high-speed machining. This phenomenon may lead to tearing off a part of the burr, accumulated on the top side and finally sticks it into the side face of the machining part. Furthermore, because of the yield strength, which is higher in AA 7075-T6 than in Al 2024-T351 (Table 2), more burrs appear on the work parts edges which led to higher resulting values of η_s under similar cutting conditions (Figure 6 and Figure 8).

As noted in (Niknam 2017), another major element which plays a critical role on burr formation morphology and size is friction. Increased friction during machining operation increases the incidence

of burr formation which eventually leads to more complex deburring operation. In fact, the effects of friction can be divided into three basic mechanisms, one due to asperity deformation, one due to adhesion and one due to particle ploughing. In orthogonal milling, friction coefficient (μ) can be approximated as (San-Juan et al. 2010):

$$\mu = \tan (\varphi) = F_r \times F_t^{-1} \quad (2)$$

Where:

φ : immersion angle

F_r : radial cutting force

F_t : Tangential cutting force

According to Eq.(2), when the tool faces friction decreases, there is a corresponding increase in the shear angle (Φ) and the accompanying reduction of the chip thickness $h(\varphi)$. Consequently, the plastic strain associated with chip formation is reduced and longer and thicker B_2 and shorter and thinner B_1 are expected. Higher levels of cutting speed and insert nose radius (R_ϵ) leads to increased F_r to a large extent, particularly where the depth of cut is smaller than the insert nose radius (R_ϵ). In addition, materials with higher machinability generate more F_r , which may lead into a reduction of friction between the chip and tool (San-Juan et al. 2010). Furthermore, during the milling operation, slight plastic deformation, serious rubbing and ploughing effects are taking place which causes heat generation, especially when high-speed cutting is used. This may lead to the formation of larger burrs on the exit side of the work parts. A complete overview of friction effects on orthogonal milling exit burrs is presented in (Niknam 2017). A comprehensive overview of the procedure used to proposed Eq.(2) is presented in (Niknam et al. 2014).

Referring to individual analysis of η_s in each material presented in Figure 7, it can be stated that depth of cut and feed per tooth are the non-statistically significant parameters on AA 2024-T351 and AA 7075-T6, respectively. However, cutting speed and cutting tool are still considered as the

statistically significant parameters on η_s in both tested materials. The effects of cutting tools may be attributed to coating and insert nose radius which seems to vary the burr formation morphology and size. This is in agreement with observations made in (Niknam 2013; Niknam et al. 2013a). As shown in Figure 6b, the cutting tool with smaller insert nose radius R_ϵ (Tool 2) led to lower resulting values of η_s . Moreover, higher cutting speed generates more cutting force in feed direction and eventually larger exit down bottom burrs are generated (Niknam et al. 2013a; Niknam et al. 2014d). This may lead to higher resulting values of burr edge occupancy η_s . According to Figure 8, using low levels of feed rate and cutting speed may lead to almost 50% reduction in calculated value of η_s in AA 2024-T351 as well as around 10% in AA7075-T6 (Figure 8). This denotes that higher levels of cutting speed are suitable for brittle materials (AA 2024-T351) than that observed in ductile materials (AA7075-T6). As noted in (Niknam et al. 2015), this trend can be attributed to friction generation which in fact tends to affect the burr formation mechanism, shape and size as well as cutting forces.

Conclusion

- Burr size reduction or localizing the burrs in inaccessible locations tend to simplify the deburring operations and in fact less manufacturing expenses are expected. It is therefore required to propose innovative parameters which can be controlled by the cutting parameters while can also be used as an index to select adequate deburring methods. To that end and in order to investigate the adequate solutions to achieve edges with minimum burrs a new index, so-called burr edge occupancy η_s was proposed in this work.
- Despite the material used, it was observed that η_s is statistically controllable by the most of cutting parameters used, in particular, cutting tool and cutting speed and family of material. The effects of cutting speed on η_s vary according to the family of material and mechanical properties, in principle brittleness and ductility.

- It was observed that low levels of cutting speed and feed rate might lead to reduced burr edge occupancy η_s by 50% on AA 2024-T351 and 10% on AA 7075-T6, which is, however, harder than the latter.
- As noted earlier, high cutting speed is more recommended on brittle materials than ductile materials. The significant effect of coating on η_s was discovered. The cutting tools with smaller insert nose radius R_ϵ led to lower resulting values of η_s .
- Generating a direct link between η_s and the widely used deburring methods is the main aspect of future works. Furthermore, the similar methodology can be conducted for different types of machining operations, in principle face milling and drilling operations as well as the various family of materials. Moreover, the proposed index can be improved by incorporating the effects of major elements affecting the burr formation morphology and size, in principle ductility of materials as well as friction generation during the cutting process.

Acknowledgment

Authors would like to acknowledge the financial support received by the Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRNT) and Iran's National Elites Foundation.

References

- Aurich, JC., Dornfeld, D., Arrazola, P. J., Franke, V., Leitz, L. and Min, S. (2009). Burrs-Analysis, control and removal. *CIRP Annals - Manufacturing Technology* **58**(2): 519-542.
- Biermann, D. and Heilmann, M. (2010). Burr Minimization Strategies in Machining Operations. *Burrs-Analysis, Control and Removal: Part 1*, 13-20.
- Chen, M., Liu, G. and Shen, Z. (2006) Study on Active Process Control of Burr Formation in Al-Alloy Milling Process. *Proceeding of the IEEE, International Conference on Automation Science and Engineering*, 8-10 Oct. 2006, Shanghai, China.
- Chern, GL. (2006). Experimental observation and analysis of burr formation mechanisms in face milling of aluminum alloys. *International Journal of Machine Tools and Manufacture* **46**(12-13): 1517-1525.
- Committee, AIH. and Knovel (2004). *ASM Handbook: Metallography and Microstructures*, ASM International.
- Dornfeld, D. and Avila, M (2004). On the face milling burr formation mechanisms and minimization strategies at high tool engagement. *Consortium on deburring and edge finishing*. University of California, Berkeley, CA.
- Gillespie, L. (1999). *Deburring and edge finishing handbook*. Dearborn, MI ,USA, Society of Manufacturing Engineers (SME).
- Gillespie, L. and Blotter, P. (1976). Formation and properties of machining burrs. *J. Eng. Ind. (Trans. ASME, B)* **98**(1): 66-74.
- Hashimura, M. and Dornfeld, D. (1995). Analysis of burr formation mechanism in machining process. Technical paper, society of manufacturing engineering (SME) –All series.
- Iwata, K., Osakada, K. and Terasaka, Y (1984). Process modeling of orthogonal cutting by the rigid-plastic finite element method. *Journal of Engineering materials and technology* **106**: 132-138.
- Klocke, F., Hoppe, S. and Fritsch, R. (2004). FE-modeling of burr formation in orthogonal cutting. *Proceeding of 7th Int. Conference on Deburring and Surface Finishing*, University of California, Berkeley, USA.
- Ko, S. and Dornfeld, D. (1991). A study on burr formation mechanism." *Journal of Engineering materials and technology* **113**(1): 75-87.
- Korkut, I. and Donertas, M. (2007). The influence of feed rate and cutting speed on the cutting forces, surface roughness and tool-chip contact length during face milling. *Materials & design* **28**(1): 308-312.
- Lauderbaugh, L. (2009). Analysis of the effects of process parameters on exit burrs in drilling using a combined simulation and experimental approach. *Journal of Materials Processing Technology* **209**(4): 1909-1919.
- Lekkala, R., Bajpai, V., Singh, RK. and Joshi, S. S. (2011). Characterization and modeling of burr formation in micro-end milling. *Precision Engineering* **35**(4): 625-637.
- Leopold, J. and Wohlgemuth, R. (2010). Modeling and Simulation of Burr Formation: State-of-the-Art and Future Trends. *Burrs-Analysis, Control and Removal*: 79-86.
- Lin, TR. (2000). Experimental study of burr formation and tool chipping in the face milling of stainless steel." *Journal of Materials Processing Technology* **108**(1): 12-20.
- Luo, M., Liu, G. and Chen, M. (2008). Mechanism of burr formation in slot milling Al-alloy. *International Journal of Materials and Product Technology* **31**(1): 63-71.

- Nakayama, K. and Arai, M. (1987). Burr formation in metal cutting. *CIRP Annals-Manufacturing Technology* **36**(1): 33-36.
- Narayanaswami, R. and Dornfeld, D. (1994). Design and process planning strategies for burr minimization and deburring. *Transactions of the North American Manufacturing Research Institute of SME* 1994. **22**: 313-322.
- Niknam, S.A. (2013). Burrs Understanding, Modeling and Optimization during Slot Milling of Aluminium Alloys
- Niknam, S.A. (2017). Modeling and experimental characterization of the friction effects on orthogonal milling exit burrs. *The International Journal of Advanced Manufacturing Technology* **91**(1): 1079-1089.
- Niknam, S.A., Zedan, Y. and Songmene, V. (2012). Burr formation during milling of wrought aluminum alloys. 20th ISME Annual International Conference on Mechanical Engineering. 16-18 May 2012, Shiraz, Iran.
- Niknam, S.A., Zedan, Y. and Songmene, V. (2014a). Machining Burrs Formation & Deburring of Aluminium Alloys Light Metal Alloys Applications 99-122.
- Niknam, S.A., Khettabi, R. and Songmene, V. (2014b). Machinability and Machining of Titanium Alloys: A Review. *Machining of Titanium Alloys*, Springer Berlin Heidelberg: 1-30.
- Niknam, S.A., Wygowski, W., Balazinski, M. and Songmene, V. (2014c). Milling Burr Formation and Avoidance. *Machinability of Advanced Materials*. J. P. Davim. London, UK, ISTE Wiley: 57-94.
- Niknam, S.A. and Songmene, V. (2013a). Experimental Investigation and Modeling of Milling Burrs. *ASME 2013 International Manufacturing Science and Engineering Conference* collocated with the 41st North American Manufacturing Research Conference, 10-14 June 2013, Madison, Wisconsin, USA.
- Niknam, S.A. and Songmene, V. (2013b). Factors governing burr formation during high-speed slot milling of wrought aluminium alloys. *Proceeding of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* **227**(8): 1165-1179.
- Niknam, S.A. and Songmene, V. (2013c). Modeling of burr thickness in milling of ductile materials. *The International Journal of Advanced Manufacturing Technology* **66**(9): 2029-2039.
- Niknam, S.A. and Songmene, V. (2013d). Simultaneous optimization of burrs size and surface finish when milling 6061-T6 aluminium alloy. *International Journal of Precision Engineering and Manufacturing* **14**(8): 1311-1320.
- Niknam, S.A. and Songmene, V. (2014d). Analytical modelling of slot milling exit burr size. *The International Journal of Advanced Manufacturing Technology* **73**(1-4): 421-432.
- Niknam, S.A. and Songmene, V. (2015). Milling Burr Formation, Modeling and Control: A Review. *Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* **229**(6): 893-909.
- Niknam, S.A. and Songmene, V. (2017). Burr formation and correlation with cutting force and acoustic emission signals. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* **231**(3): 399-414.
- Olvera, O. and Barrow, G. (1996). An experimental study of burr formation in square shoulder face milling. *International Journal of Machine Tools and Manufacture* **36**(9): 1005-1020.
- Rangarjan, A. (2005). Optimization of face milling process- Tool path and process planning techniques, Ph.D Thesis, University of California at Berkeley, USA.
- San-Juan, M., Martín, Ó and Santos, F. (2010). Experimental study of friction from cutting forces in orthogonal milling. *International Journal of Machine Tools and Manufacture* **50**(7): 591-600.

Schäfer, F. (1975). Entgraten, Krausskopf.

Songmene, V., Kouam, J., Zaghbani, I., Parson, N and Maltais, N (2013). Global Machinability of Al-Mg-Si Extrusions. Aluminium Alloys - New Trends in Fabrication and Applications. P. Ahmad Zaki, InTech.

Tiabi, A. (2010). Formation des bavures d'usinage et finition de pieces Master of Science, École de technologie supérieure.

List of Tables

Table 1. Cutting parameters used

Table 2. Mechanical properties of studied aluminum alloys (Committee et al. 2004)

List of Figures

Figure 1 : Slot Milling Burrs (*adapted from* (Niknam et al. 2013a))

Figure 2. Slot milled 6061-T6 aluminum machined part with (a) large burrs (b) acceptable burr size (Niknam et al. 2013a))

Figure 3. Measurement values of burr (Niknam 2013)

Figure 4. The main components of the burr edge occupancy η_s

Figure 5. Experimental devices: (a) 3-Axis CNC machine (b) Cutting tool used (c) Work parts configuration

Figure 6. (a) Pareto chart of η_s ($R^2=0.75$); (b) Main effect plot of η_s

Figure 7. Pareto chart of η_s in (a) AA 2024-T351 ($R^2=0.79$) (b) AA 7075-T6 ($R^2=0.77$)

Figure 8. 3D contour plot of η_s under for (a) AA 2024-T351; (b) AA 7075-T6 when using the depth of cut 1 mm and tool #1

Table 1

Experimental parameters	Level		
	1	2	3
A: Material	2024-T351	-	7075-T6
B: Cutting tools /Coating	TiCN	TiAlN	TiCN + Al ₂ O ₃ + TiN
Insert nose radius (mm)	0.5	0.81	0.5
C: Depth of cut, a_p (mm)	1	-	2
D: Feed per tooth f_z (mm/z)	0.01	0.055	0.1
E: Cutting speed v_c (m/min)	300	750	1200

Draft

Table 2

Material	Mechanical Properties		
	Brinell Hardness	Yield Strength	Elongation at Break
Al 7075-T6	150	550 MPa	11 (%)
Al 2024- T351	120 HB	325 MPa	20 (%)

Draft

Figure1

Figure 2

Figure 3

Figure 4

Figure 5

5(a)

5(b)

5(c)

Figure 6

(a)

(b)

Figure 7

(a)

(b)

Figure 8

(a)

(b)

Test No.	η_s %	
	AA 2024-T351	AA 7075-T6
1	50.000	83.621
2	81.034	83.621
3	79.310	83.621
4	83.621	83.621
5	90.517	83.621
6	91.379	83.621
7	83.621	91.379
8	90.517	97.414
9	93.966	96.552
10	61.864	99.153
11	92.373	83.898
12	95.763	98.305
13	78.814	91.525
14	91.525	93.220
15	90.678	98.305
16	94.068	98.305
17	92.373	94.915
18	98.305	96.610
19	87.069	87.931
20	87.931	88.793
21	93.103	100.000
22	90.517	91.379
23	91.379	83.621
24	100.000	87.931
25	89.655	87.069
26	88.793	91.379
27	92.241	90.517
28	88.983	88.983
29	100.000	100.000
30	91.525	93.220
31	94.915	90.678
32	92.373	100.000
33	89.831	94.068
34	94.915	89.831
35	95.763	92.373
36	90.678	90.678
37	89.655	87.931
38	100.000	99.138
39	91.379	100.000
40	93.103	95.690
41	88.793	100.000
42	89.655	98.276

43	91.379	96.552
44	95.690	100.000
45	95.690	99.138
46	91.525	90.678
47	100.000	98.305
48	91.525	100.000
49	93.220	98.305
50	94.068	100.000
51	83.898	100.000
52	91.525	100.000
53	93.220	97.458
54	92.373	99.153

Draft