The study of fine-cleaning treatment for removal of burrs in screw rotors

V A Lebedev¹, G V Serga², M M Chaava¹, L V Chunakhova¹, Al-Obaidi Luai Mohammed Radgab³

¹Don State Technical University, Rostov-on-Don, Russia
²Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia
³Middle Technical University, Irak

Abstract. The essence of technological systems, the main working element of which are screw rotors represented as spatial objects with original geometric shape of perimeter has been disclosed. The results of investigations on fine-cleaning treatment for removal of burrs in screw rotors have been displayed. Geometric dimensions, shape and structure of burrs have to depend on mechanism of their formation, which is caused by energy-force factors of contact tool interaction on treated surface alongside with physic-mechanical changes in surface layer. The conditions of the most efficient use of screw rotors for fine-cleaning treatment for removal of burrs are defined. This research suggests the dependence for estimation of intensity of metal removal depending on various technological parameters of fine-cleaning treatment process in screw rotors and offers practical recommendations on how to select its constituent coefficients.

1. Introduction
During the processing of machine parts on metal-working equipment, burrs are formed at tool orifice from contact with treated surface. The necessity to remove burrs is caused by the requirements of operating conditions or the intention to ensure the marketable condition of parts. Fine-cleaning treatment for removal of burrs runs into difficulties due to the variety and complexity of the shapes of surfaces from which burrs are formed. The development and introduction of screw rotor technological systems into production practices enables to find an effective solution to this problem.

Screw rotors are spatial objects with original geometric perimeter shape, in which parts and granules of the processing medium perform simultaneously continuous rotational movement around the working body axis and translational movement, permanently moving along the horizontal axis of the working body rotation. Such movements in screw rotors are provided by the loading masses due to the design of their external surfaces, which are discretely arranged along the perimeter, by flat elements of different shape and types of sizes oppositely directed to screw lines along their external surface. The advantage of rotary-screw process systems implies the possibility of combining the parts processing with their transportation [1-19].

The purpose of the present study is to determine the degree of influence on the metal consumption of the in-process part and, as a consequence, the intensity of the process, causing the removal of burrs, granulation and grain of abrasive operation environments, the volume of their loading into the working zone during fine-cleaning operations in machines, equipped with a working body in the shape of a screw rotor and the development on this basis some practical recommendations on their choice taking into account the specifics of the burrs.
2. Burrs Formation Mechanism and their Characteristics

Geometrical shape, dimensions and properties of burrs depend on method of their formation on surface, which is based on inherent mechanism of conduct of the process, characterized by energy-forced factors of contact tool impact on treated surface and accompanying physico-mechanical changes in surface layer.

Four types of burrs can be identified according to this fundamental characteristic feature:
- burrs formed during separation of the cutting edge of the tool from the surface of the work-piece;
- burrs formed under the action of compressive stresses during volume or surface plastic deformation;
- burrs formed as a result of metal building-up;
- burrs formed by melting and hardening.

Table 1 clearly represents methods of mechanical and electro-physical treatment, grouped by methods of burrs formation on the surface of parts, as well as main characteristic features of burrs formed by them.

Table 1. Methods of mechanical and electro-physical treatment grouped by methods of burrs formation on the surface of parts

| Methods of burrs formation | Methods of processing | Features of burrs |
|----------------------------|-----------------------|-------------------|
| Processes related to removal of materials during cutting | Stitching, milling, drilling, cutting, longitudinal cutting | Burrs with sizes corresponding to cutting depth |
| Melting and hardening | Electro discharge machining, laser processing, casting, casting in the chill mold, formation of plastic, agglomeration, welding, hard-facing, forging | Welding fillets, welding spots around the weld, mold flash |
| Processing by plastic deformation | Press forging, rolling of gears and threads, etc. Unloading on the presses. Methods of surface plastic deformation | Big and small burrs caused by extrusion, flash stamp after the forging |
| Metal extension on the part surface | Electrolytic coatings, paint coatings, metal spraying | Film burrs |

Studies of the shape and structure of castle-nut burrs, formed after milling its slots has shown the following. In the zone of burrs connection with the main metal Figure 1 their thinning takes place, which is explained not only by burr bending in the process of its occurrence, or by peculiarities of temperature mode, but also by the removal of metal layer from the base (leg) of the burrs when the cutting tool goes beyond the part limits. The observed curl of the burrs metal indicates that they possess temper brittleness Figure 2. The structure of the processed metal consists of ferrite and pearlite. Along the profile outline of processed surface and full-width of a burr – there is a partial decarburization to a depth of 0.4 mm. Carbon burnout is caused by high temperature in the tool-part contact zone.

Structural transformations in the material of burrs and processed surface have not been noticed. However, the grain deformation is recorded in the zone of connection of metal chips and base metal Figure 3. This is due to the fact that at the exit of the cutting tool the cutting forces significantly exceed the strength of the metal layer, which is removed, deformed and thus, deformation of metal grains happens in the direction of the cutting force. Metals having stress concentrators and under dynamic load conditions tend to transform into brittle state.
**Figure 1.** Photo of the burrs micro block and areas of its connection to the metal of the part (triple increase)

**Figure 2.** Micro-slice of burrs (hundredfold magnification)

**Figure 3.** Micro-slice illustrating the hardness of the burrs and legs metal (of its base)
The parts are made of steel st. 3. Micro-hardness is determined on hardness testing machine «ПМТ-3» on load of 50 g. The hardness of the main burrs material is equal to HRC = 25.5 mPa.

3. Efficiency evaluation of metal output and burrs removal in screw rotors

The carried out studies included consideration of the processes of breaking the burrs of metal parts after machining (milling, precision, drilling, etc.) in screw rotors using abrasive operating environment. The investigated parts were made of materials with a body-centered cubic arrangement, which usually have a tendency to brittle destruction due to the presence of impurities inside them.

It has been found that the most efficient use of screw rotors for fine-cleaning treatment removal of burrs formed by methods of material removal from the surface. Burrs formed by methods of plastic deformation of material, by melting and hardening in screw rotors without special devices are hard to remove efficiently. Besides, it requires long treatment duration, which leads to the change of sizes and quality of the surface of processed parts. In order to eliminate this factor, it is recommended to process such parts in screw rotors by fixing them in special protective devices, which allow particles of operating environment to actively influence on burrs, flash, etc., simultaneously covering the rest of the processed parts’ surfaces.

Such devices shall move freely or forcibly along the longitudinal axis of the screw rotor. The processing time of parts with thick burrs, in the shape of flash, from hard-to-process materials is provided by flexibility of installations on the basis of screw rotors and ability to quickly reconfigure them to the required processing modes.

Under conditions of fine-cleaning treatment of parts in screw rotors, the burrs are subjected to variable impact load of granules of operation environment, therefore, the criterion of burrs material ability to resist impact action of operation environment particles (burrs tendency to brittle destruction) is their fracture toughness.

The fracture toughness of steels and a number of other materials significantly decreases over a certain range of temperatures. Therefore, one of the ways to reduce the time of burrs removal and improve the technical and economic characteristics of the parts OZO in screw rotors could be to pre-cool the parts, which can be easily implemented in machines based on screw rotors.

In order to evaluate efficiency of fine-cleaning treatment in screw rotors, there has been proposed the analytical dependence establishing connection of output of metal with main technological factors of machining process:

\[
\Delta Q = n^{1.5} HB^{-0.9} t K_d K_z K_d K_v K_c K_p^n
\]

where \( n \) – is a screw rotor rotational frequency, rpm (round per minute);
\( HB \) – material hardness;
\( t \) – processing time, min;
\( K_d, K_z, K_d, K_v, K_c, K_p^n \) – coefficients reflecting influence on processing process intensity in screw rotors: dimensions of operating environments granules, abrasive granules grain, weight of parts, volume of screw rotor loading, process liquid, rotor geometry.

As a result of carried out studies, practical recommendations have been proposed to determine the values of coefficients included in the above suggested dependence and presented in the form of nomograms in Fig. 4, 5, 6, 7, 8 in the Table 1.
Figure 4. Nomogram for determination of $K_d$ coefficient, reflecting influence of operating environment dimension granules $d_p$ on the intensity of metal output.

Figure 5. Nomogram for determination of $K_{3p}$ coefficient, reflecting influence of abrasive granules environments $\delta_3$ on the intensity of metal output dimensions.

Figure 6. Nomogram for determination of $K_v$ coefficient, reflecting influence of screw rotor fill capacity factor $\frac{V_m}{V_{p\cdot k}}$ on the intensity of metal output.
Figure 7. Nomogram for determination of $K_p$ coefficient, reflecting influence of part weight $P$ on the intensity of metal output

Figure 8. Nomogram for determination of $K_p^n$ coefficient, reflecting influence of screw rotor class on the intensity of metal output

Table 2. $K_c$ coefficient values, reflecting influence of process liquid on the intensity of metal output [19]

| Type of process liquid                                      | $K_c$ |
|-------------------------------------------------------------|-------|
| 2% sodium carbonate solution in water                       | 1.2   |
| 1% oleic acid in 2% sodium carbonate solution               | 2.27  |
| 1% CuSO4 solution in water                                  | 2.91  |
| H2SO4 hydrous solution and chromic anhydride of weak texture| 4.5   |
| 1% oleic acid in turpentine                                 | 4.86  |
| 1% stearic acid in kerosene                                 | 6.8   |

4. Conclusion
The complex of studies has shown that rotary-screw technological systems allow to effectively deal with issues related to fine-cleaning treatment of parts having various burrs which differ in mechanism of their formation on the parts surface, in shape and in structure.
Proposed analytical dependence on evaluation of processing intensity in screw rotors, reinforced by practical recommendations on selection of coefficients included in it, makes it possible to control the process of fine-cleaning treatment of parts in rotary-screw technological systems and on this basis to select the most rational processing conditions ensuring the required quality of parts surface and process efficiency.

References

[1] Serga G.V. Implementation of L.N. Koshkins’s ideology in vibro-hardening technology based on the example of screw rotors / G.V. Serga, V.A. Lebedev. Vestnik RSTU named after P.A. Solov’ev. 2017. 2 (41). 126–132.

[2] Lebedev V.A. Increase of efficiency of finishing-cleaning and hardening procession of details based on rotor-screw technological systems / V.A. Lebedev, G.V. Serga, A.V. Khandozhko MEACS, 2017 IOP Publishing IOP Conf. Series: Materials Science and Engineering 327 doi: 10.1088/1757–899X/327/4/042062.

[3] Sekisov Aleksandr. Rotary-screw systems for rotary Kilns/ Aleksandr Sekisov and Georgy Serga // E3S Web of Conferences 91. 02034 (2019): https://doi.org /10.105/e3sconf/20199102034 TRACEE-2018.

[4] Marchenko Alexey. Creating Methodology for Calculating the drive of the drive of the working parts of the Equipment based on the original screw sieves, screw housing and screw drums/ Alexey Marchenko, Georgy Serga IAPS 2019, 06(03). 6855–6860 ISSN 2349–7750 https://www.iajps.com INDO American Journal of Pharmaceutical Sciences.

[5] Serga G.V. Investigation of physical phenomena occurring in the contact zone of the blanks of bulk materials during their movement in screw drums, by methods of the theory of similarity, engineering and computer graphics / G.V. Serga, D.G. Sery, A. Yu. Marchenko Bulletin of the Bryansk State Technical University. 2019 6 (79). 20–29.

[6] Babichev A.P. Fundamentals of vibration technology / A.P. Babichev, I.A. Babichev – Rostov n / a: Publishing Center of DSTU, 2008. – P. 693.

[7] Butenko V. I. Finishing surface treatment of parts: methods, devices, tools / V.I. Butenko. - Rostov-on-Don: Publisher. Center DSTU, 2016. – 219 p.

[8] Bezyazchny VF Method of similarity in mechanical engineering technology [Text] / VF Bezyazchny. - M: Mechanical Engineering, 2012. – 317 p.

[9] Tamarkin M? Tichshenko E., Shvedova A.S. Optimization of Dynamic Surface Plastic Deformation in Machining Russian Engineering Research 2018, 38, 9. 726–727.

[10] Fyodorov V.P. Determination of parametric relia-bility of machining technological systems by simu-lation technique / V.P. Fyodorov, M.N. Nagorkin, A.V. Totai IOP Conf. Series: Materials Science and Engineering. 124 (2016) 012053.

[11] Schubnell J., Eichheimer C., Ernould C., Maciolek A., Rebelo–Kornmeier J., Farajian M. The influence of coverage for high frequency mechanical impact treatment of different steel grades. Journal of materials processing technology. 2020. 277. Article number 116437.

[12] Pesin M.V. Improving the Reliability of Threaded Pipe Joints. Russian Engineering Research 2012. 32/2. 210–212.

[13] Ankudimov Yu.P., Ankudimov P.Yu. Operational capabilities of the vibration treatment method with a complex energy impact on the technological system // Strengthening technologies and coatings. 2012. 8.

[14] Quality assurance of products in technological complexes / S.A. Chizhik [and others]; under total. ed. M.L. Heifetz. – Minsk: Belaruskaya Navuka, 2019. – 248 p

[15] Zuev L.B., Barannikova S.A., Lunev A.G., Kolosov S.V., Zharmukhambetova A.M. Basic Relationships of the Autowave Model of a Plastic Flow Russian Physics Journal. 2019. 61. 1709–1717.
[16] Suslov A.G., Babichev A.P., Kirichek A.V. and other Technology and tools for finishing and hardening processing of parts by surface plastic deformation: a reference book. In 2 volumes. T. 2. / Under total. ed. A.G. Suslova. - M.: Mashinostroenie, 2014. – 444 p.: ill. – ISBN 978–5–94275–709–0; ISBN 978–5–94275–711–3.

[17] Ibatullin I.D. Kinetics of fatigue damage and destruction of surface layers: monograph / I.D. Ibatullin. – Samara: Samar. state tech. un-t, 2008. – 387 p.

[18] Modern technologies of shaping / V.A. Lebedev, A.I. Boldyrev, M.A. Tamarkin, Yu.P. Ankudimov. Moscow: INFRA-M, 2019. 320 p.

[19] Kolganova E.N., Fedorov A.V., Bachmanova O.A. Investigation of the influence of the shape of the burr section on the time of its removal during vibration processing in the environment of free abrasives // In the collection: Life cycle of construction materials (from receipt to disposal) Materials of the IX All-Russian Scientific and Technical Conference with international participation. Irkutsk: Publishing house IRNITU, 2019. – P. 14–22.

[20] Kropotkina Elena, Zykova Marina, Shein Alexander, Kapustina Natalya Application of roller burnishing technologies to improve the wear resistance of submerged pump parts made of powder alloys Mechanics & Industry 19, 705. 2019. 1-11.