Kovács, Zs.; Viharos, Zs. J.; Kodácsy, J.: Manufacturing of Twist-Free Surfaces by Magnetism Aided Machining (MAM) Technologies, *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, World Academy of Science, Engineering and Technology*, Vol. 10. No. 12., 2016., pp. 1969-1973.
PISSN:2010-376X, EISSN:2010-3778

Manufacturing of Twist-Free Surfaces by Magnetism Aided Machining (MAM) Technologies

Zs. Kovács, Zs. Viharos, J. Kodácsy

Abstract — Currently grinding is commonly used as the finishing operation to manufacture seal mating surfaces and bearing surfaces, especially in the automotive industry. It would lead to more resource-efficient production if the cost- and energy-intensive grinding process could be replaced by machining with magnetic aided technologies. The machined surfaces by turning or grinding usually have twist structure on the surfaces, which can convey lubricants such as conveyor screw. To avoid this phenomenon have to use special kind of techniques or machine, for example, rotation turning, tangential turning, ultrasonic protection or special toll geometries. All of these solutions have a high cost and difficult usability. In this paper the authors describes a system and summarizes the results of the experimental research carried out by the authors mainly in the field of Magnetic Abrasive Polishing (MAP) and Magnetic Roller Burnishing (MRB). These technologies simple and also cheap while result the twist-free surfaces. During the tests C45 normalized steel was used as workpiece material which was machined by simple and Wiper geometrical turning inserts in a CNC turning lathe. After the turning was used the MAP and MRB technologies to reduce the twist of surfaces. The evaluation was completed by advanced measuring and IT equipment.

Keywords— magnetism, finishing; polishing, roller burnishing, twist-free

I. Introduction

THE turning always creates a twisted surface, namely regardless of the machined material or whether that is hardened or not respectively. This surface has regular structures corresponding to a thread shaped structure (twisted) which, by the advance of the tool along the rotating workpiece are producing a screw pitch.

The reason for this phenomenon is that the feed motion of the tool will cause twist structures on the surface of workpiece which can cause leakage. For example, the surface which is produced by conventional turning tool can poduce tipical roughness and spiral pattern which responsible for the conveyor effect in the gap between the seal ring and the shaft.

Zs. Kovács is with the Department of Manufacturing Science and Technology, Budapest University of Technology and Economics, Budapest, H-1111 Hungary (corresponding author to provide E-Mail: kovacszs@manuf.bme.hu, Phone: +36-30-974-7791, Fax: +36-76-516-399).

J. Viharos is with Institute for Computer Science and Control of the Hungarian Academy of Sciences, Budapest, H-1111 Hungary (E-Mail: viharos.zsolt@sztaki.mta.hu).

J. Kodácsy is with the Kecskemét University Faculty of Mechanical Engineering and Automation, Izsáki Street 10, Kecskemét, H-6000 Hungary, (E-Mail: kodacsy.janos@gamf.kefo.hu).

Grindings (cylindrical and plunge) are accustomed manufacturing techniques for creating twist-free surfaces. However, it has been established that it also produces twist structure, because of the dressed grinding wheel, where the dressing diamond create the twist structure on the surface of whell which able to copy onto the surface of workpiece.

There are also other techniques to make a twist-free surfaces like tangential turning, vibration-processing methods or start-stop turning [1], [2].

The main problem about these techniques to requiring special machine structure and thus demanding significant investment. Morevor, also disadvantages the special tool, limited length and not to mention thh long manufacturing time.

II. Structure of Twist Surface

Twist structures are characterized by microscopic structures which are comparable with a thread structure on a shaft surface. The Fig 1 shows the surface of a turned shaft schematically. The parameters are described in the Mercedes-Benz standard MBN 31007-7 in 2009 [3], [4].

DP – period length (mm),
Dγ – twist angle (° ’ ”),
Dt – twist depth (μm),
DG – number of threads ( ),
DF – theoretical supply cross section (μm^2)

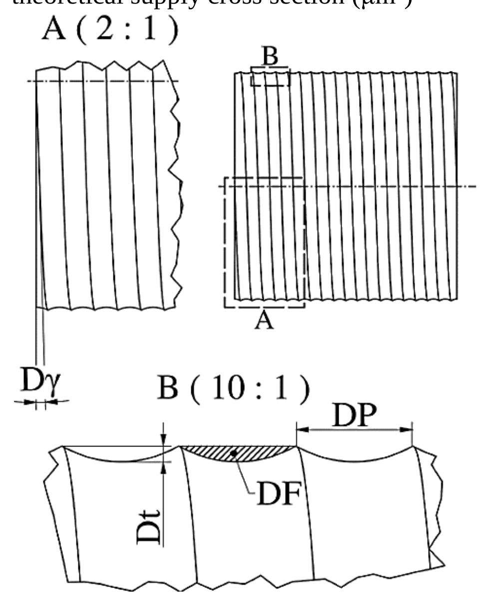


Fig. 1. Parameters of twist surface [5]

The parameters are dependent on process parameters (feed, nose radius etc.). During the rotation of a turned shaft, the liquid entrains in the circumferential direction and is deflected axially because of the twist structures [5].

The industry is currently looking for alternative manufacturing processes, for example hard turning, milling, burnishing or laser polishing. Besides these processes there are two similar technologies, the Magnetic Abrasive Polishing (MAP) and the Magnetic Assisted Roller Burnishing (MARB) which are also able to produce twist-free surface.

III. MAM TECHNOLOGIES

Denomination Magnetism Aided Machining (MAM) comprises a number of relatively new industrial machining processes (mainly finishing and surface improving) developed presently, too.

The magnetic force makes these processes simpler and more productive. Machining force is generated by an adjustable electromagnetic field between two magnetic poles within the working area ensuring the necessary pressure and speed difference between the tools (abrasive grains, pellets or rollers) and the workpiece [6].

A. Magnetic Abrasive Polishing (MAP)

The polishing for decrease of surface roughness and increase of resistance against wear, corrosion and produce twist-free surface. Magnetic Abrasive Polishing is one such unconventional finishing process developed recently to produce efficiently and economically good quality finish. In this process, usually use ferromagnetic particles are sintered with fine abrasive particles (Al_2O_3, SiC, CBN or diamond. The MAP equipment for cylindrical surfaces was adapted to a universal engine lathe (Fig. 2.) [7].

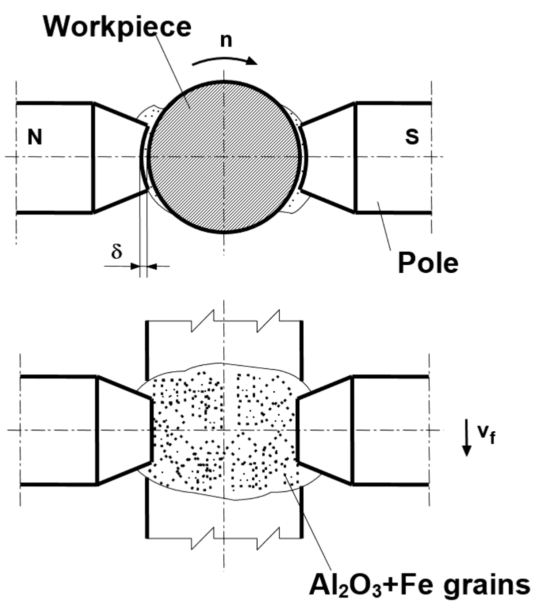


Fig. 2. MAP technology [7]

B. Magnetic Assisted Roller Burnishing (MARB)

The main goal of roller burnishing is to achieve high-quality smooth surfaces or surfaces with pre-defined surface finish. During the process one or more balls plastify deform the surface layer of workpiece (Fig. 3.).

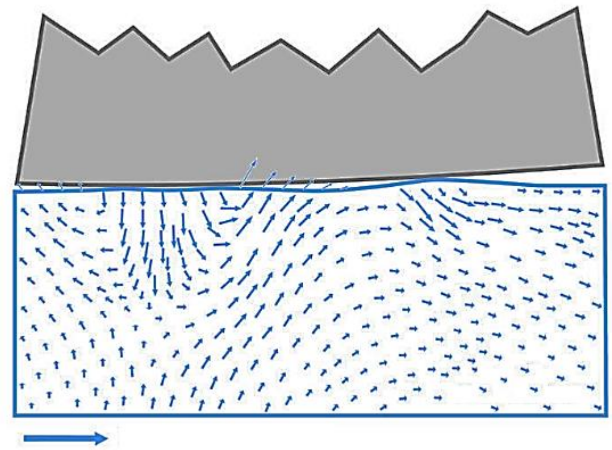


Fig. 3. Material flow [8]

In case, if this stress is higher than yield strength of the material, the material near the surface starts to flow. As the ball moves across the workpiece surface, the peaks of surface are pressed down, almost vertically, into the surface and the material then flows into the valleys between the peaks as you see in (Fig. 4.) [8].

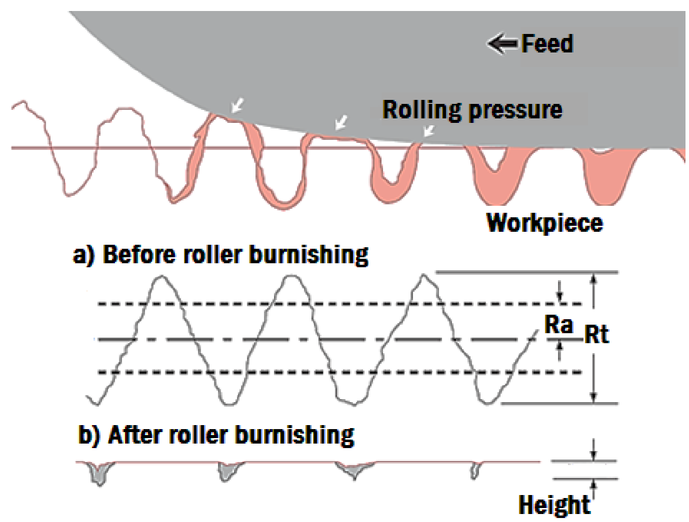
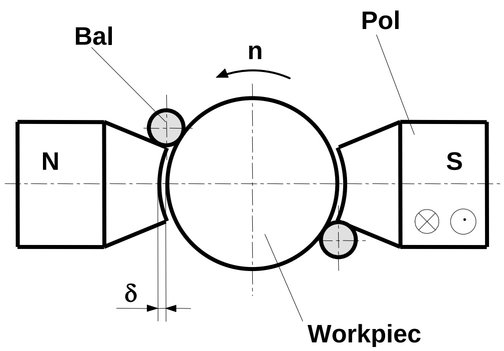


Fig. 4. Evolution of surface by roller burnishing [8]

Most of manufacturing processes which result high-quality surfaces can be replaced by roller burnishing (e.g. fine turning, grinding, superfinishing, lapgrinding). The roller burnishing technology able to reduce the surfaces roughness (Rz <10 μm) and increase the hardness in micron depth [8].

For roller burnishing was applying mechanical force to press the rolling ball onto the surfaces. To avoid the harmful deformation by mechanical pressing the necessary pressure and relative speed between the tools and the workpiece are ensured by the magnetic force.

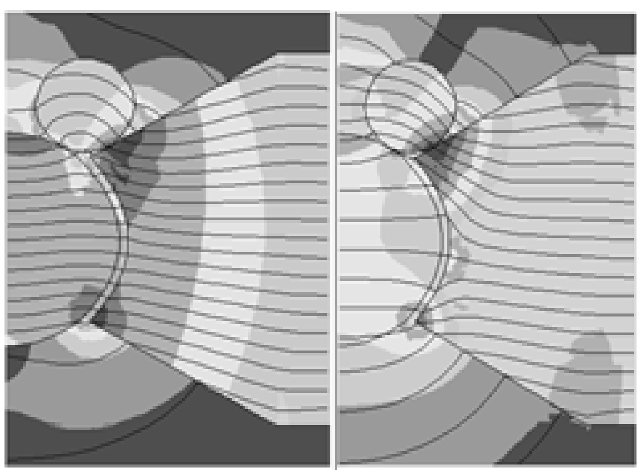
The burnishing operation was performed by hardened steel balls of 6…12 mm diameter (HRC = 60), with v = 20…800 m/min peripheral speed and f = 0,05…0,3 mm/rev feed. The balls were set above or under the jaws in radius-shaped slots preventing the balls from any kind of axial displacement. The magnetic force kept the balls in the slots and – depending on the scale of magnetic induction – pressed them to the surface of the workpiece with a force of 50 ... 100 N. The balls could freely roll perpendicularly to the rotational axis of the workpiece following the eventual macro-unevenness of the cylindrical surface. The burnishing operation consisted of a double-stroke motion of the slide along the rotating workpiece, in feed direction.



The magnetic roller burnishing equipment for cylindrical surfaces was adapted to a universal engine lathe (Fig. 5.).

Fig. **5**. MARB technology [7]

Important about this technology that the magnetizable steel could be burnished more effectively than the nonmagnetic Al-alloy, due to the higher magnetic force. In case, if the workpiece material nonmagnetic the magnetic force line not able to press the ball to the surface (Fig. 6).



(a) (b)

Fig. 6. Magnetic lines for steel a) and Al-alloy b) workpiece material [7]

For the modelling system, the magnetic force components were computed using the (2, 3, 4) equations [7].

$$F_x = V \cdot H \cdot \left(\frac{\partial H}{\partial x}\right)(\mu - \mu_0) \quad (1)$$

$$F_y = V \cdot H \cdot \left(\frac{\partial H}{\partial y}\right)(\mu - \mu_0) \quad (2)$$

$$F = \left(F_x^2 + F_y^2\right)^{\frac{1}{2}} \quad (3)$$

where *F* is the magnetic force (including the components too), *V* is the volume of the burnishing ball, *H* is the intensity of the magnetic field, μ and μ_0 are magnetic permeability of the ball material and the vacuum, respectively.

IV. Experimental Setup

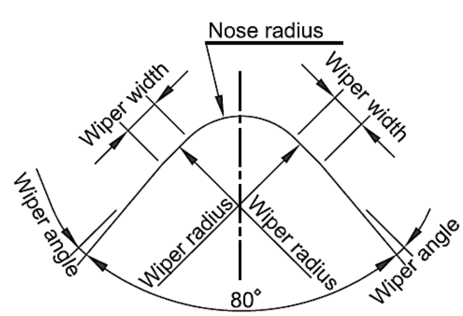
In the performed investigations the shaft surfaces were manufactured purposefully by turning using different cutting tool. Then the surface was machined MAM technologies (MARB and MAP), see in the Fig. 7.

(a)

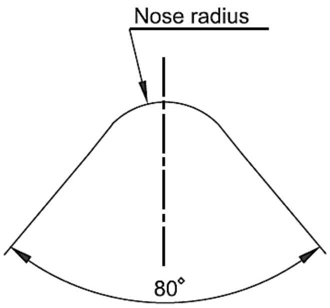
(b)

Fig. 7. Picture about the MA Polishing a) and Roller Burnishing b)

Furthermore was made a grinded part as a reference to be able to compare the surfaces made by different technologies. During processing the workpieces C45-type steel with a diameter of 26 mm and a length of 100 mm were selected as processing elements. Cutting tool was inserts with wiper geometry (WNMG080404W-MF2, TP2501) and conventional inserts (WNMG080404-MF2, TP2501) (Fig 8.).



a)



b)

Fig. 8. Geometry of Wiper a) and conventional b) insert [4]

The MAM equipment is able to work as polishing and rolling function where the electromagnetic poles were fixed onto the slide of the lathe. In the tests the voltage (U = 40 V), current (I = 10 A) (direct current, adjustable) and the generating magnetic induction (B = 0,96 T) were the same under rolling and polishing too. The generated magnetic induction was reduced (B = 0,75 T) with polishing grain because of the applied Al_2O_3 shielding properties. The magnetic jaws (poles) surrounded the workpiece with a δ = 3 mm gap (clearance).

The turning, rolling and polishing technological parameters shows the Table 1.

TABLE 1.
TECHNICAL PARAMETERS OF MACHINING OPERATIONS

Turning	
f (mm/min)	0,133
v_c (m/min)	117
a_p (mm)	1
Rolling	
f (mm/rev)	0,1
v_r (m/min)	22
Polishing	
t (min)	1,5
v_p (m/min)	62

f=feed; v_c cutting speed; a_p= cutting deep; v_r= rolling speed; t= time; v_p= polishing speed

V. EVALUATION

After the manufacturing there are six different surfaces (grinded, turned by simple and Wiper insert). As first step were measured the surfaces roughens by MITUTOYO Formtracer SV-C3000 roughness tester. The measured results see in Table 2.

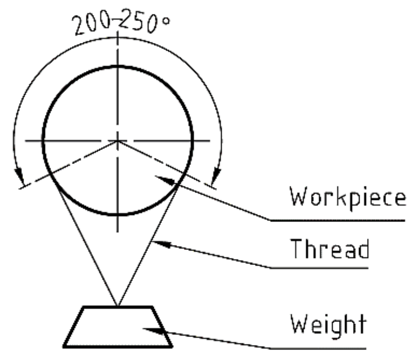
TABLE 2.
ROUGHNESS VALUES AFTER MACHINING

Technology	Ra (µm)	Rz (µm)
Grinded	0,54	3,43
Turned (simple)	1,2	6,09
Rolled	0,40	2,40
Polished	0,96	4,93
Turned (Wiper)	0,45	3,05
Rolled	0,27	1,92
Polished	0,38	2,79

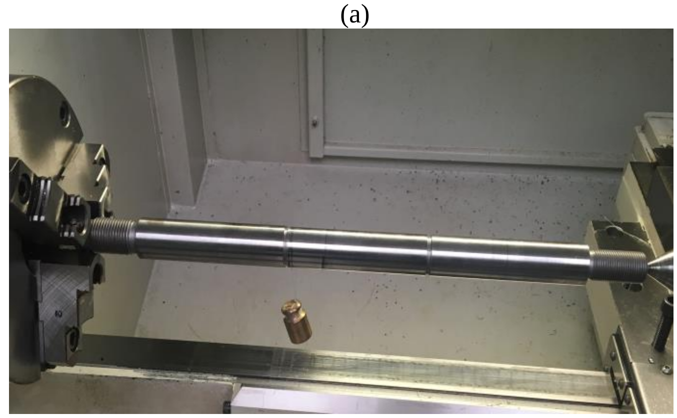
Than was measured the twist surface by thread method. This method is a simple and fast method because it is consist of a thread and weight. The thread made from steel, plastic or wool (e.g.: fishing line or sewing thread). In this research were used steel thread where the steel diameter of 0,04 mm. The weight depends on the applied thread material and diameter so in this case is 50 g [9].

A. Measuring procedure

During the measurement has to rotate the workpiece in horizontal position and superimpose the thread with the weight (Fig 9.).



(a)

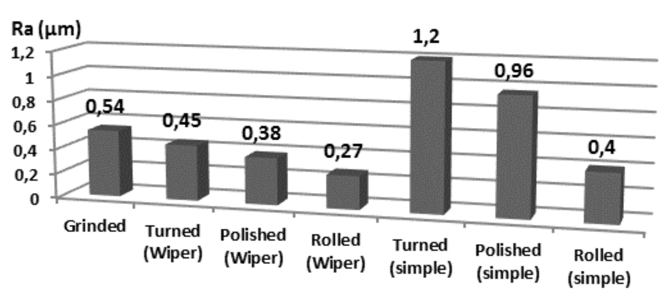


(b)

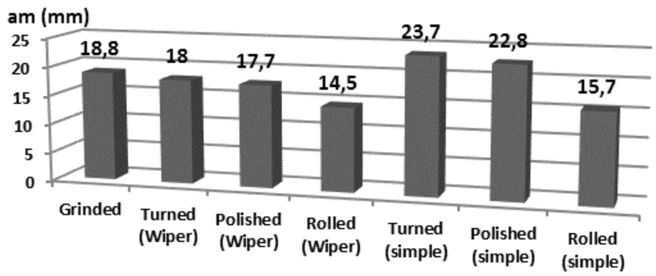
Fig. 9 Thread method a) [9] and during measurement b)

The measuring takes one minute and during this time the workpiece peripheral speed 20 m/min. Then have to measure the displacement of thread (a_1) and must be performed the rotation the other direction and also have to measured it (a_2). The average of two values (3) is the characteristic number of twist surface (a_m) [10]. The results are presented in Fig. 8.

$$a_m = \frac{a_1 + a_2}{2} \text{ (mm)} \qquad (3)$$



(a)



(b)

Fig. 8. Measurement results of Ra roughness a) and characteristic number b) of twist surface

VI. Conclusion

The research shows that MAM technologies are new manufacturing opportunity for surfaces to obtain desired functions such as surfaces with tribological function.

According to the expectations the Wiper insert produced a less than twist surfaces compared to the simple one and as you see in the Fig. 8. a) that the grinded surface were worse than the rolled.

According to the Fig. 8. b) instead of grinding can be machined with MAMRB which is faster, economical, easier and some case does not require workpiece transfer. Also there are negatives, like accuracy (size and position) which depends on the previous manufacturing.

Acknowledgment

The authors gratefully acknowledge the support of the SECO Company to provide the necessary cutting inserts.

References

[1] S. Jung, W. Haas, Grundlehrang Dichtungstechnik. University of Stuttgart (2006)

[2] G. Lechner, H. Raab, Einfluss der Wellenlaufflache auf das Dichtverhalten von Radialwellendichtringen. Final report, BMWi/AiF Nr. 10670 (1998), pp.: 59-73.

[3] MBN 31007-7, 2002. Daimler AG, Stuttgard (2001), pp.: 312-316

[4] A. Schubert, R. Zhang, P. Steinert, Manufacturing of Twist-Free Surfaces by Hard Turning, Procedia CIRP (2013), pp.: 294

[5] J. Kundrák, I. Sztankovics, K. Gyáni, Analysis of the Theoritical Values of Several Characteristic Parameters of Surface Topography in Rotational Turning, World Academy of Science, Engineering and Technology International Journal of Mechanical Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:5, (2014), pp.: 908-914

[6] Kodácsy, J. Líska: Magnetic Assisted Roller Burnishing and Deburring of Flat Metal Surfaces. Advanced Materials Research Vol. TransTech 472-475 Publication Ltd, Zürich, 2012, pp.: 908-911.

[7] J. Kodácsy, J. Danyi, A. Szabó, Gy. Fülöp: Magnetic Aided Roller Burnishing Metal Parts. 7th International Conference on Deburring and Surface Finishing, UC Berkeley (USA), 2004, pp.: 375-378

[8] Ecoroll Corporation prospect: Tools & Solutions for Metal Surface Improvement. Milford, USA, 2006, pp.: 6, 16, 28, 31, 91.

[9] ZFN 5032:2013-10 (industrial standard)

[10] J. Kundrák, N. Nagy, Twisted surface machined by cutting (Forgácsolással megmunkált felületek sodrásossága), GYÁRTÁS 2015 Konferencia, 2015, November 20., Budapest, GépGyártás szakfolyóirat, INDEX: 25344, ISSN 0016-8580, pp.: 116-118.