EXAMINATION OF OUTER AND INNER LUBRICATION WITH MINIMUM VOLUME OF LUBRICANTS WHEN DRILLING OF GREY CAST IRON

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Abstract:
The researchers of Department of Technical Preparatory and Production Engineering at College of Nyíregyháza, and the Department of Production Engineering at University of Miskolc has started a common research project for investigation the drilling experiments of a cast iron workpieces using minimal volume lubrication. At our experiments measurements were performed and compared using different amount of coolants and lubricants when outer coolants admission. In this paper the measured results were compared with those ones which were got earlier by researchers of Department of Production Engineering at University of Miskolc when they used twist drills having inner coolant channels at their experiments.
Keywords: *Environmentally Friendly Machining, Examination, Thrust, Torque, Surface roughness, Vibration*

1. INTRODUCTION

The Department of Production Engineering of University of Miskolc (UM) and the Department of Technical Preparatory and Production Engineering of College of Nyíregyháza (CN) had common research project on the field of environmentally friendly machining. The Department of Production Engineering of UM begun researches on this field in an European Community project at 1994, which title was "Environmentally Conscious Machining – Reducing or neglecting the volume of lubricants at drilling" (Program: STD-2EC, ERB CIPACT 930167) [3], [4], [8]. During this project drilling was examined when using twist drill having inner cooling channels. From that time the topic is up-to-date even today [6], [7], [9]. Next to the drilling with twist drills having inner cooling channels we are dealing with drilling with outer cooling as well.

Aims of our present drilling experiments: determination of changing of

- thrust (F_f) and torque (M_c),
- different wears of cutting tool (corner wear: VB_E and flank wear: $VB_{3,5}$),
- surface roughness of machined surfaces (R_a)
- values of velocity of vibration

during drilling when *outer lubrication* with minimum volume of coolants and lubricants. Most of present measured data are compared by the results got by UM when drilling with twist drills having inner cooling channels [3], [4].

2. CIRCUMSTANCES OF EXPERIMENTS

The twist drill used for drilling experiments has the following features: Ø10,2 mm, K20 Gühring WRDG DIN 6537 (monolith carbide, coating TiAlN, having inner coolant-lubricating channel).
Material of specimen: grey cast iron, EN-GJL-200 (MSZ EN 1561), in which we made holes (lengths are 30 mm) during serial experiments.
Realization of minimum volume of lubrication was done by outer admission of the lubricants to the superficies of the twist drill by vaporizer type „NOGA MINI COOL" (volume per hour range is $10 cm^3/h \div 250 cm^3/h$, with continuous regulation).
To the cutting experiments oil without chlorine type „OMV cut XU" was used.
Execution of experiments was done by milling machine type MU-250 with the cutting parameters detailed as follows:

Revolution number of spindle of milling cutter:	$n = 2250$ rev/min	Volume of coolants and lubricants:	$Q = 10$ and $28 cm^3/h$
Feed:	$f = 0,18$ mm/rev	Feed rate:	$v_f = 405$ mm/min
Cutting speed:	v_c=72,06 m/min	Time of machining:	$t = 0,074$ min

Measurement of thrust (F_f) and torque (M_c) was done by two component KISTLER dynamometer type 9271 A. Measurement of corner wear (VB_E) and flank wear ($VB_{3,5}$) was done by two different ways. On first method we photographed the twist drill in vertical position on measuring microscope, and later from the digital photo we determined the values of the corner wear (VB_E) and flank wear ($VB_{3,5}$) by application of a computer programme. On second method the measurement of the cutting tool wear was done by the use of CCD camera. The surface roughness (R_a) of the holes was measured by MITUTOYO measuring instrument type SJ-201. Measurement of vibration was done by SKF MICROLOG CMVA 60-EN FFT vibration analyzer.

3. EVALUATION OF MEASUREMENT DATA

3.1 Results of measurements of thrust (F_f) and torque (M_c)

It can be stated, on the base of Fig. 1. that oscillation of F_f and M_c is significant during the drilling process, furthermore values of F_f and M_c are considerably increasing by increasing of drilling length.

From Fig. 1. and 2. it can be read off that at *outer lubrication* values of F_f and M_c are significantly increasing by increasing the length of drilling. Increasing the volume of lubricants from 10 cm^3/h to 28 cm^3/h the values of F_f are decreasing approximately 20-40 %, while values of M_c are decreasing approximately 20-100 %. The decrement is increasing by increasing of length of drilling.

During examination, on the base of comparing of inner and outer lubrication of making 30 mm length holes for the values of thrust and torque, we can state as follows: (Fig. 1.-2.) [3]:

- The values of thrust and torque always lower at inner lubrication than outer lubrication when supplying the same volume of coolants and lubricants.
- While related the values of thrust and torque at supplying 10 cm^3/h volume of lubricants the difference is great between inner and outer lubrication (50-100 %), while at 28 cm^3/h volume of lubricants this difference very small (5-10 %).
- At inner lubrication the 10 cm^3/h volume of lubricants is sufficient for lubrication of twist drill, while at outer lubrication, for at least 28 cm^3/h, necessary for reaching the necessary satisfactory lubrication.

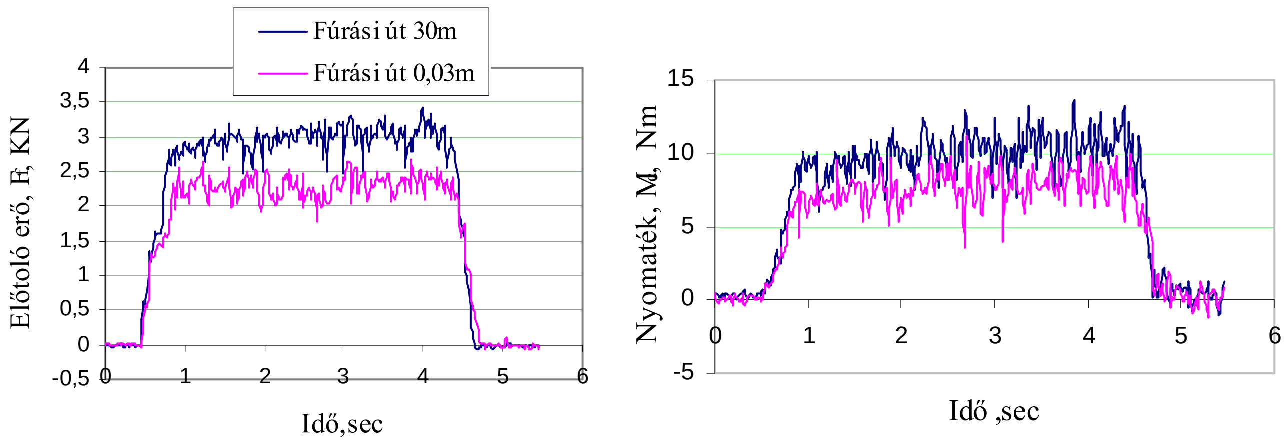

Fig. 1. *Changing of thrust (F_f) and torque (M_c) at drilling length (outer lubrication)* Q=28 cm^3/h

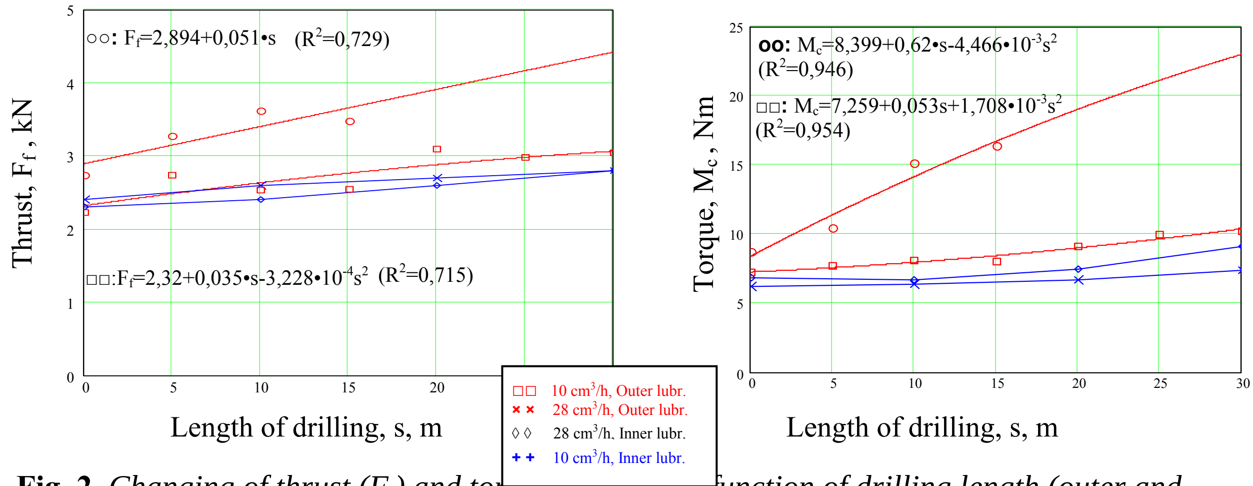

Fig. 2. *Changing of thrust (F_f) and torque (M_c) as the function of drilling length (outer and inner lubrication)*

3.2. Results of measurements of cutting tool wear

For characterisation of wear out of the twist drill we have chosen the corner wear (VB_E) and flak wear ($VB_{3,5}$) [1], [2]. The flank wear was measured on the direction radius at 3,5 mm from centre line on the main cutting edge, wear width into the direction of flank. Determination of values of wear was done using digital photo where the magnification was N=300 by Corel computer program. The worn drill with the reference lines which are necessary for measurent is shown on Fig. 3. Of course the measurement of the cutting tool wear can be done by the using of CCD camera as well [8] (Fig. 4.). From analysing of measuring results it appears that the measurement results of cutting tool wear is in harmony with the measuring results of thrust and torque that is at the volume of 10 cm^3/h of lubricants at outer lubrication the greater cutting tool wear causes greater increase of thrust and torque (Fig. 5.) [5].

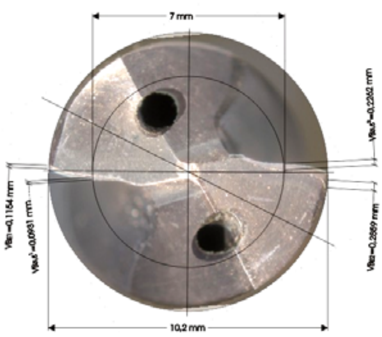

Fig. 3. *Measured values of cutting tool wear after s = 25 m drilling length (Q = 28 cm^3/h)*

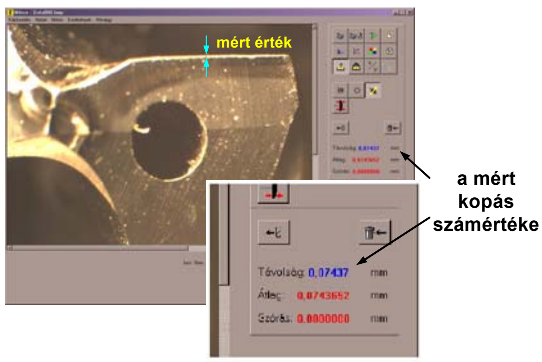

Fig. 4. *Measurement of flank wear of a twist drill by CCD camera [8]*

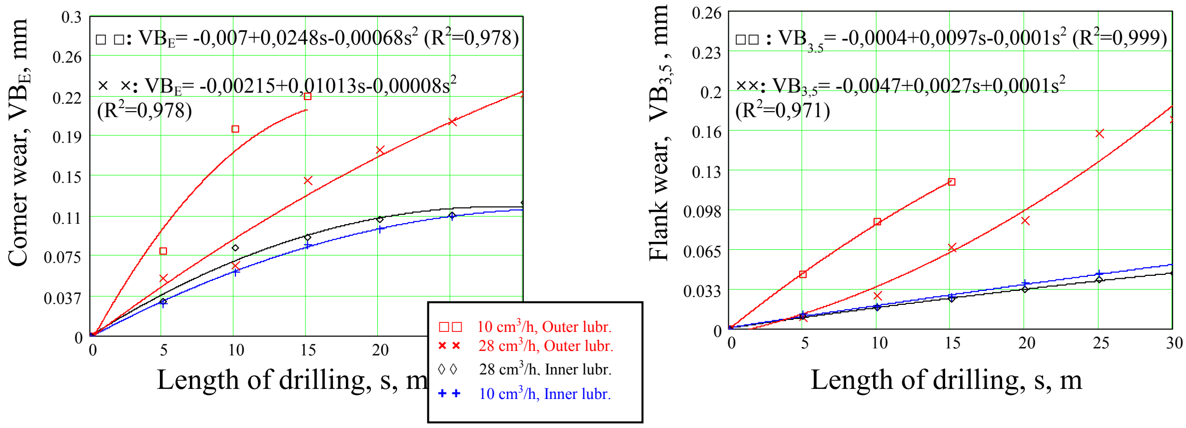

Fig. 5. *Changing of corner wear (VB_E) and flank wear ($VB_{3,5}$) as the function of drilling length (outer and inner lubrication)*

On the base of comparing of the effect of inner and outer lubrication on cutting tool wear we can state as follows (Fig. 5.) [3]:

- At the case when the supply of lubrication is the same the value of corner wear (VB_E) and the flank wear ($VB_{3,5}$) is always smaller than at inner lubrication.
- While at inner lubrication the increase of volume of lubrication does not reduce significantly the cutting tool wear up to that time at outer cooling the increase of volume of lubrication reduced significantly the cutting tool wear.
- While at inner lubrication 10 cm^3/h volume of lubrication is sufficient for lubrication twist drill, till that time at outer cooling at least 28cm^3/h volume of lubrication necessary for getting the necessary lubrication.

Of course, these statements are changing when the width of the specimen is greater, L=50 mm or 100 mm, because in case of $L \geq 5D$ the effect of outer lubrication decreasing very much.

3.4. Results of measurements of surface roughness

The changing of the measured average surface roughness (R_a) in the machined hole as the function of length of drilling is shown on Fig. 6. at inner and outer lubrication. It can be seen from the figure, that the standard deviation of measured values of surface roughness is expressive (its cause can be the improper stiffness of the milling machine, and occurring additional vibrations when drilling). As expected, the measured values of surface roughness were increased by increasing length of drilling, but that caused astonishment that when increasing of volume of lubricants from the value of 10 cm^3/h to 28 cm^3/h we could register worse values of surface roughness.

From comparison of values of surface roughness at inner [3] and outer lubrication (minimum volume of lubrication) (Fig. 6.) it appears that in the case of the same volume of lubrication (in the range of 10-28 cm^3/h) at outer cooling we got better values of surface roughness. Furthermore, it can be stated, that the same tendency can be observed both in inner and outer lubrication, that is, by increasing of volume of lubricants from 10 cm^3/h to 28 cm^3/h, the value of surface roughness of the drilled hole is deteriorated. The clarification of the cause of the phenomenon requires further examination.

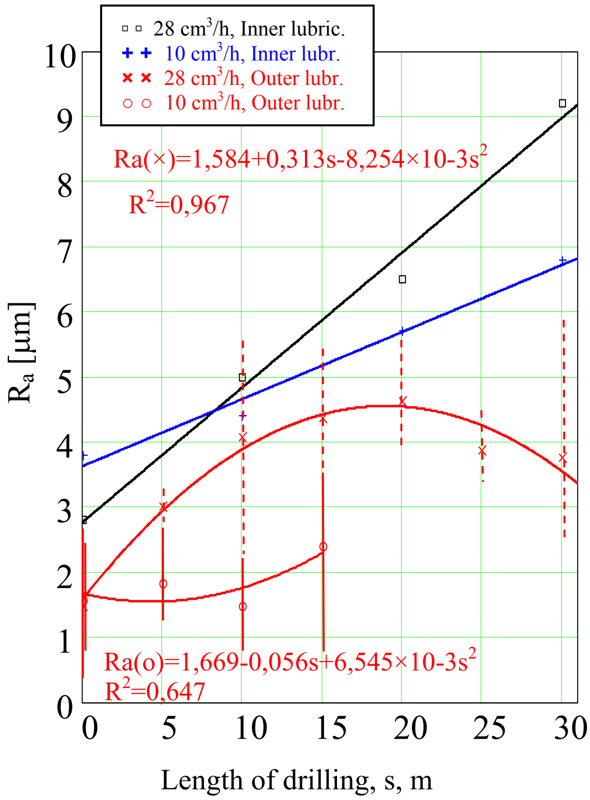

Fig. 6. *Changing of surface roughness (R_a) as the function of drilling length (outer and inner lubrication)*

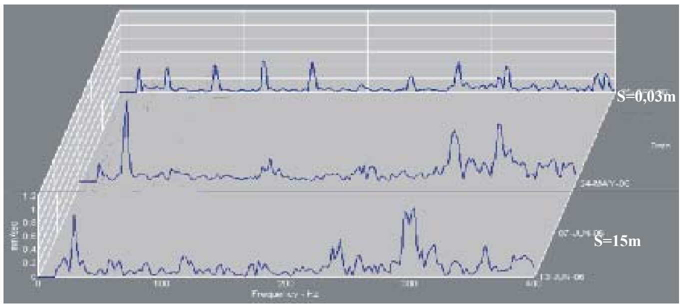

Fig. 7. *Changing of values of summarized velocity of vibration measured in horizontal direction as the function of drilling length at outer lubrication (Q = 28 cm^3/h)*

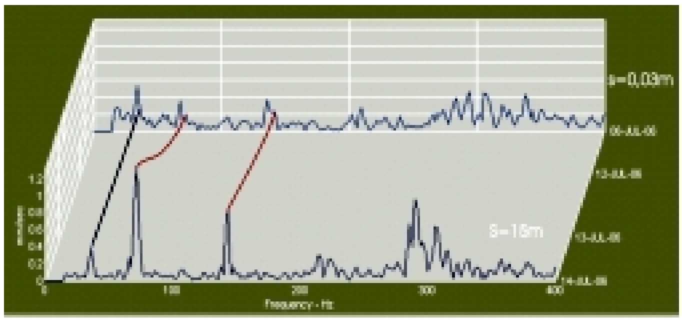

Fig. 8. *Changing of values of summarized velocity of vibration measured in horizontal direction as the function of drilling length at outer lubrication (Q = 10 cm^3/h)*

3.4. Results of measurements of velocity of vibration

The values of measured summarised vibrations in horizontal and vertical directions in the function of length of drilling were increased significantly together with the cutting tool wear. Probably this is the cause of increase of surface roughness in the function of the increase of length of drilling (Fig. 7.-8.). When the volume of lubrication was 10 cm^3/h, the measured summarised vibration velocity was smaller. Maybe this can be one explanation, that we registered better surface roughness at outer lubrication.

4. SUMMARY

After comparing of our present and previous measuring results, we can conclude as follows:

- By reduction of volume of lubrication at drilling of cast iron with outer lubrication, we managed to get appropriate cutting conditions too.
- While at inner lubrication the volume of $10cm^3/h$ was enough for getting positive effects, at outer lubrication for getting appropriate effects, we had to use at least $28cm^3/h$ amount of lubrication.
- At inner and outer lubrication it can be noticed similar tendency, that is, when increasing of value of volume of lubricants from 10 cm^3/h to 28 cm^3/h, the value of the average surface roughness is deteriorated.
- The summarised values of vibration velocities are increasing in the function of length of drilling.

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