TURNING TOOL LIFE TEST FOR CUTTING FLUID EVALUATION

Key words: Machining enterprises, tools, turning tool life test, cutting fluids, test method

1 SCOPE
The test method specifies a procedure for evaluating cutting fluids in turning. In this method the following relevant parameters are considered: workpiece material and its geometry, tool material and its geometry, fluids to be tested, general cutting conditions, tool life/tool wear. The aim of the method is to provide information about cutting fluid performance primarily to the enterprises using cutting fluids in their production processes. The test method follows closely the specification of ISO 3685 [1] to which reference is made.

2 FIELD OF APPLICATION
The method is developed to be applicable in normal workshop conditions using conventional equipment available in workshops. The test can be carried out using the desired number of workpiece materials, tool types, cutting fluids and combinations of cutting speed, depth of cut and feed rate values.

3 REFERENCES
1. ISO 3685:1993 (E), Tool life testing with single point turning tools.
5. ISO 5608-1995-09-01 (E), Turning and copying tool holders and cartridges for indexable inserts - Designation.

4 DEFINITIONS
4.1 Cutting speed, depth of cut and feed rates
Cutting speed, depth of cut and feed rate are chosen in accordance with ISO 3685 [1]. Depth of cut and feed rate are held constant but the cutting speed is varied. The tolerance on the feed rate is according to ISO 229 [2] but the tolerance on depth of cut is ±5%.

The tool is selected according to ISO 3685 [1].

4.2 Tool life criterion
Catastrophic failure is used in this procedure as the tool life criterion. The catastrophic failure is deemed to have occurred when the tool wear is so large that the tool cannot do any cutting successfully and the insert nose breaks off.

5 SAMPLING
5.1 Workpiece
It is recommended that the composition of the workpiece material for the cutting fluid tests is similar to the material generally used in normal production. From the practical point of view it is beneficial to carry out the cutting tests using circular bars as the workpiece. This is recommended if this is relevant to production conditions. The grade, chemical composition, physical properties and any heat treatment shall be reported. All the workpiece material used in the tests must be from the same manufacturing batch. The quantity of material needed depends on the number of tests to be carried out. It is important to reserve enough material for the tests in advance so that the use of material from different manufacturing batches may be avoided.

The workpiece is a circular bar with a maximal length/diameter ratio of 10 for the final diameter of the bar.
5.2. Tool
A tool material similar to that in production tools is recom-
mended for the cutting fluid tests because small changes in
tool material often have a significant influence on the
behaviour of the tools in cutting.

5.3 Cutting fluid
Cutting fluid is the test variable in this procedure. The evalu-
ation of the fluids in this method is based on the comparison
of tool life between different fluids.
The cutting fluid shall be clearly specified either by trade
mark or composition of the active elements, the actual con-
centration, hardness of water (when used as a diluent) and
the pH value of the solution or emulsion.
The mixture ratio is determined from an economical/technical
point of view. The mixture ratio of the fluid shall be
checked with a refractometer before the test series. The
mixture ratio may not vary by more than ±0.5 %. The mixture
ratio shall be reported in the test report.

6 METHOD OF TEST

6.1 Principle
Before starting the test, it should be ascertained that lathe,
workpiece and tools fulfil all the requirements of ISO 3685
Five trials with each parameter combination is the minimum
number required to give sufficient statistical data.

6.2 Apparatus
Apparatus including turning lathe shall be according to ISO
3685 [1]. The turning lathe shall be equipped with a variable
speed spindle drive covering the range of spindle speed to
be used. Spindle power of the machine tool must be suf-
ficient for the test conditions.
A refractometer shall be used for checking the mixture ratio
of the cutting fluid.
An optical microscope or a magnifying glass with a magni-
fication of at least 10x is required for the recommended
checks on the tool. If tool dimension and geometry are
measured, suitable equipment for this purpose is needed.

6.3 Preparation of test samples
6.3.1 Workpiece
The workpiece shall be prepared according to ISO 3685 [1].
The workpiece shall be cleaned from all foreign matter
before turning operations begin. The workpiece dimension,
fastening and other conditions shall be reported in the
greatest possible detail.

6.3.2 Tool
It is recommended that the inserts are checked before con-
ducting the cutting tests. Only inserts with no notches or other
defects on the cutting edges shall be used in the tests. Before
cutting every tool shall be cleaned from all foreign matter.

6.3.3 Cutting fluid
The pH value of the cutting fluid shall be measured before
the test series with indicator paper and it shall be reported
in the test report. The correct values can be supplied by the
fluid supplier.
The fluid reservoir and the pipes shall be carefully cleaned
between the tests each time the cutting fluid is changed.
Cleaning shall be carried out with the appropriate cleaning
agent.

6.4 Procedure
The test procedure shall be started with a warm up proce-
dure; the spindle of the machine tool is rotated and cutting
fluid is circulated. The duration of this procedure must be
sufficient to ensure proper stabilisation of the fluid mixture
ratio and temperature. During this procedure the mixture
ratio and other conditions of the fluid shall be checked and
the temperature of the fluid shall be measured at the end of
the period. All readings shall be recorded.
The cutting speed is determined so that the average tool life
is not greater than 15 minutes at the minimum speed and
not less than 30 seconds at the maximum speed.
The machine tool shall be set to the required cutting condi-
tions. If necessary, a preliminary tool life test as described
in ISO 3685 Annex E [1] shall be carried out.
A pre-cut is performed on the test material with a special
pre-cut insert. This insert is selected in order to reduce
cutting force to the minimum and therefore minimise surface
hardening.
A turning test is performed until catastrophic failure of the
insert occurs. If cutting has to be continued on the same
workpiece after the catastrophic failure has occurred, an
intermediate cut is made with a separate insert.
The flow rate of the cutting fluid shall not be less than 3 l/
min for each cubic centimetre per minute of metal removal
rate, whichever is larger. The actual flow rate range of the
cutting fluid with its tolerance shall be reported. Cutting fluid
shall be allowed to flow continuously during testing. The
volume of the fluid in the reservoir should be at least ten
times the flow rate per minute. The temperature of the cut-
ting fluid during the tests shall be 23 ± 3°C. Fluid tempera-
ture shall be measured during the tests and reported in the
test report.
In a turning process the main variables of interest are cutting
speed, feed rate and depth of cut. Depth of cut and feed rate
are held constant but cutting speed is varied.
6.5 Expression of results

The comparison between different cutting fluids is based on tool life results. The tool life times achieved with a certain cutting fluid are compared with those achieved with identical cutting parameters using other cutting fluids.

Catastrophic failure is used as a criterion. The tool life $T_c$ is plotted directly against the cutting speed $v_c$, which will provide tool life curves.

Plotting the coordinates $(v_{c1}, T_{c1}), (v_{c2}, T_{c2})$, etc. obtained on a double logarithmic cutting speed versus tool life diagram (same scale along both axis) will produce a $v_c - T_c$ curve.

These $v_c - T_c$ curves may be considered linear within a certain speed range. The equation for this linear portion of the curves is written:

$$v_c \times T_c^{-1/k} = C$$

where

- $v_c$ is cutting speed, in metres per minute;
- $T_c$ is the tool life, in minutes;
- $k = \tan(\alpha)$ defines the slope of the tool life curve;
- $C$ is a constant.

The values of $k$ and $C$ in the above equation shall be reported. Methods for the determination of $k$ and $C$ are given in section 11.3 in ISO 3685 [1].

6.6 Accuracy

In the case of full scale tool life ($v_c - T_c$) evaluation under conventional conditions, in order to interpret the results with statistical reliability, the procedure proposed in F.4 of the Annex F in ISO 3685 [1] shall be used.

6.7 Test report

A data sheet for each cutting fluid is used for recording and evaluation of the data. This sheet is shown on the following page.
<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Cutting fluid evaluation</th>
<th>Series no:</th>
</tr>
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<tbody>
<tr>
<td>Ordered by</td>
<td>Date</td>
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</tbody>
</table>

**Cutting fluid**

- Name __________________________
- Mixture ratio ________ %
- Volume _____ l
- Flow rate _____ l/min
- Number of nozzles ______

**Workpiece**

- Name and type __________________________
- Composition (%) __________________________
- Dimensions: d _____ mm, l _____ mm
- Hardness: ______

**Tools**

- Manufacturer and material __________________________
- Material: Composition (%) __________________________
- Tool holder __________________________
- Overhang ________ mm

**Machine tool**

- Name and type __________________________

**Cutting conditions**

- Depth of cut ________ mm
- Length of cut ________ mm

**Test results**

<table>
<thead>
<tr>
<th>No</th>
<th>( v_c ) [m/min]</th>
<th>( T_c ) [min]</th>
<th>( x = \log v_c )</th>
<th>( y = \log T_c )</th>
<th>( xy )</th>
<th>( x^2 )</th>
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<td>( \Sigma y = )</td>
<td>( \Sigma xy = )</td>
<td>( \Sigma x^2 = )</td>
<td>( \Sigma y^2 = )</td>
<td></td>
</tr>
</tbody>
</table>

\( (\Sigma x)^2: \) Feed rate:

\( (\Sigma x) / n: \) Cutting fluid:

\( (\Sigma x \times \Sigma y) / n: \) Comments and deviations from the procedure:

\( x = \Sigma x / n: \)

\( y = \Sigma y / n: \)

\( k = (\Sigma xy - (\Sigma x \times \Sigma y) / n) / (\Sigma x^2 - (\Sigma x)^2 / n): \)

\( C = 10^{\Sigma x / n - k}: \)

Standard deviation:

Signature: