Ergonomics design of power tools is a matter of finding the best compromise between all the ergonomic factors involved. An example could be to choose between lowering the weight of the tool or to lower the emitted noise by a more advanced and heavier muffler.

In this paper a method is presented that can be used to evaluate power tools from an ergonomic standpoint, when used on a specific workplace. The method was first presented 10 years ago and has since been successfully used by several big companies. The method has now been slightly revised and updated.

Eight ergonomic factors covering the most important aspects of power tool ergonomics given scores on a common scale. The result is presented as a bar graph. From the information in the graph it is easy to judge the tool on the workplace from an ergonomic point of view.

Power tools, Ergonomic evaluation

1 Background
Ergonomics is often used in the sense ergonomic design. However for industrial power tools the word ergonomics should be used to describe all parameters that affect the interaction between the operator and his/her tool on a specific workplace.

1.1 Ergonomic background
Many different parameters are involved in the interaction between the operator and his/her tool. Different persons tend to rank the parameters differently. For one person the noise may be regarded as very important while for another the load on the operator may be regarded as the most important parameter. This evaluation method is an attempt to do an objective evaluation of a power tool when used by an operator on a workplace. A powertool can not be evaluated stand-alone. It must be evaluated in the environment where it is used. The load on the operator from the weight of the tool may e.g. be significant on a workplace where the tool is hand held but be of almost no significance on a workplace where the tool is hanging in a balancer. A number of important parameters are defined and they are ranked on a common scale to make it possible to compare them.

1.2 Ergonomic evaluation factors
Mr Bo Lindquist from Atlas Copco presented this method to evaluate power tools from an ergonomic standpoint 10 years ago, in the book Power Tool Ergonomics. Since then the method has been used successfully by many companies.
In the book, eight ergonomic parameters are defined. These are: Handle design, External load, Weight, Temperature, Shock reaction, Vibration, Noise, Dust and oil. To be able to compare the different factors towards one another some means to objectively compare them must be found.

The method has now been revised and a second edition of the book has been printed.

2 Evaluation principle

2.1 The common scale
A common scale ranging from 0 to 50 is used in the book. A score of 0 means that there is virtually no ergonomic load on the operator while a score of 50 represents a load that is unacceptable also for very short exposure times.

2.2 Rules for the common scale
Some rules have been set up for the transformation of measures of the different parameters to scores on the common scale ranging from 0 to 50. As mentioned before a score of 0 should represent an insignificant ergonomic load on the operator from that parameter. A score of 20 is chosen to represent the maximum load that should be accepted for a full 8 hour working day. The score of 50 is given to a measure that can cause problems after only a short exposure time.

3 The evaluation
In this part some examples are given describing how the ranking has been built up for different parameters.

3.1 Example handle design
The handle of a hand tool is the part that has most direct contact with the hand or hands of the operator. Thus, handle design directly affects the usability and comfort level of the tool during operation. From an ergonomic viewpoint, the aim is to design handles which allow the operator to apply maximum force and grip. Good handle design also results in natural working postures and eliminates harmful local stresses on the operator’s hands.

Fig 1 Different types of tools require different handles.
A number of parameters all affecting handle design are evaluated separately. In fig 2 the table for handle circumference is shown. Each parameter gets a score and the total score for handle design is than the sum of all the individual scores.

3.2 Example external load

When using a hand-held power tool, the operator’s hand, arm and shoulder system are subjected to the forces generated by the tool in use and the weight of the tool. Excessive load of this type may cause fatigue or, at worst, result in damage to the operator’s musculoskeletal system. To minimize this risk, the level, frequency and duration of the load must be taken into consideration when designing the workstation and selecting the tools.

The load on the operator is limited by the force generating capacities of individual operators. A common measure of their capacity is muscular strength, i.e., the maximal force that a group of muscles can develop under prescribed conditions. Since the muscles must be activated voluntarily, some authorities refer to muscular strength as producing Maximum Voluntary Contraction (MVC) levels.

Normal muscle strength values are usually obtained from volunteers belonging to specified groups (e.g., male, female, working population, domestic population, etc.) under prescribed conditions. It should be noted that there are substantial individual variations in muscular capacity data – the strongest is 6-8 times stronger than the weakest.

Of the many factors which may influence muscular strength, gender, accounts for the largest difference in average strength values. The strength of the average woman is approximately two-thirds that of the average man. This average covers the capacities of many different muscles. The strength of the different muscles in the hand-arm-shoulder system of a woman can be anywhere between 35% and 80% of that of a man.

Only a few scientific reports deal with wrist torque capacity. Torque is an important part of the external load from power tools. In this evaluation method semi empirical values for wrist torque is used based partly on scientific reports and partly from experience. The values are given in fig3.
In the evaluation a score for external load is calculated based on the relation between the load needed to perform a specific action and the MVC for that load. The MVC is first reduced due to a number of influencing factors e.g. frequency of operation and duration per day. The relation between the actual force and the reduced MVC is defined as the R-value. This R-value is then used to determine the score for the load using the graph in Fig 4. More information on how the MVC is reduced can be found in the book.

3.3 Example vibrations

All machines vibrate to some extent. Depending on the design, the vibration can cause malfunction, fatigue and breakage of the tool. When operators are exposed, vibration can also cause health problems. In power tools the magnitude of vibration is determined by oscillating forces acting on the machine mass, the excitation of the natural frequencies of machine parts, and vibration from the process itself.

In the European Machinery Directive 98/37/EC, defining basic safety standards, it is stated that the manufacturer is obliged to declare vibration values. The values should be obtained by the use of an appropriate European standard (EN). ISO 8662, EN 50144.

<table>
<thead>
<tr>
<th>Sitting and standing</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supination</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Pronation</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Radial flexion</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Ulnar flexion</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Dorsal flexion</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Palmar flexion</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

Fig 3 Maximal Voluntary Contraction values for wrist torque in Newton-meters (Nm). These are practical values based on scientific results and experience.

Fig 4 The score for external load can be obtained from this figure, using the R-value for each type of external load present.
and EN 60745 are used for pneumatic and electric power tools. The ISO 8662 is also converted to EN 8662. In the operator’s instructions it should either be stated that the value is below 2.5 m/s², or the actual value should be stated. The declared values are regarded as general information on the machine.

In July 2005, national legislation based on directive 2002/44/EG, the so-called Physical Agents (Vibration) Directive came into force. The regulations stipulate the actions an employer needs to take to control exposure to vibration for his workforce. The regulations include an action value and a limit value for the exposure to hand-arm vibration. Both values are exposure values integrated for an eight-hour working day. Above the action value 2.5 m/s² the employer must take action to reduce exposure to vibration. Above the limit value 5 m/s² the employer must take immediate action to stop further exposure, find out why the limit was exceeded and ensure that it does not happen again.

A CE standardization group has been working with the question of how to implement 2002/44/EG, the Physical Agents (Vibration). In a technical report CEN/TR 15350 they suggested that the first rough exposure assessment could be based on the declared values multiplied by a given correction factor. For most industrial tools the correction factor is 1.5. For chipping hammers in fettling operations the correction is set to 2. Another important correction is for tools with declared values below 2.5 m/s². For those tools, 2.5 m/s² should be used as the declared value in exposure assessments even when a lower declared value is given.

This evaluation method uses the guidelines in CEN/TR 15350. The declared value with proper correction together with the exposure time for the work situation analysed is used together with the graph in fig 5 to find the score for vibration.

**Fig. 5** Score for vibration using as input $A(8)$, the vibration exposure integrated over an 8-hour working day

### 4 Evaluation results

The evaluation results for the 8 parameters are displayed in a bar graph (fig 6). Looking at the graph it becomes very obvious what is the most important ergonomic parameter to address to improve the situation for the operator. The average score can also be calculated and that figure can be used as a measure of the ergonomic quality of the tool. It has been requested that all tools should have the average score presented as general
information. This is difficult to do because the score is only valid for a tool on a specific workplace. To give tool specific values would then require that a standard workplace was defined and it can be questioned how relevant such a figure would be.

Fig 6 Bar graph showing the overall result for the evaluation of the Impulse Nutrunner ErgoPulse EP9.

5 Experience
This evaluation method has now been used for about 10 years. It has proven to be very useful to compare different tools used on the same workplace. It is also used to evaluate how design changes on a workplace can affect the workplace ergonomics. It has been noted that a more advanced representation of the work situation including more possibilities to define postures would be a great improvement. At the moment we have just noted the need and as a possible future development of the method.

6 References