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# THE RISK RELATED TO GRINDING TOOL FRACTURE

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**Abstract**. *Parameters for defining hazard level of possible grinding tool breakage are specified in this paper. Appropriate mathematical model to reveal this hazard is described. Reliability of this model has been analyzed on example related to grinding tool fracture of standard workshop grinder.*

**Key words**: *risk of hazard, rate of safety, and grinding tool*

## 1. INTRODUCTION

The mechanical wound hazard comes from the machine moving parts, which are unguarded and accessible for the attendant's parts of body at cleaning, lubrication or some other operator's activity. These hazards are specially expressed while bursting of parts of material which is treated at the grinding tool breakage. Bursting parts have relatively high kinetic energy, and they can cause injuries of operators and other persons who are present in endangered area.

However, if machine has built-in safety devices, it absolutely does not mean that operator is not endangered during its attendance. This is especially expressed in the use of the grinding tool, which presents major hazard for the attendants at its breakage.

There are no objective criteria for the evaluation of risk, for the machine attendants. Because of these reasons, here is given a mathematical model of risk of hazard determination, i.e., evaluation of applicable measures of the grinding wheel mechanical safety, [1,3].

## 2. PARAMETERS FOR DETERMINING RATE OF HAZARD

At the treatment by grinding, the main hazard for the operator is possibility of sudden breakage and bursting of the broken parts of the (grinding wheel) tool. The grinding

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wheel breakage and bursting can rarely happen. However, it is necessary to emphasize that consequences in the case of the grinding tool breakage are very unfavourable, both for the attendant safety and for the machine- grinder damage. Because of relatively high circumferential velocity and considerable weight of a broken part of the grinding wheel, the centrifugal force is appeared which is destructive for the protective guard. The broken parts go through the protective guard and they can injure the operator, fig. 1.

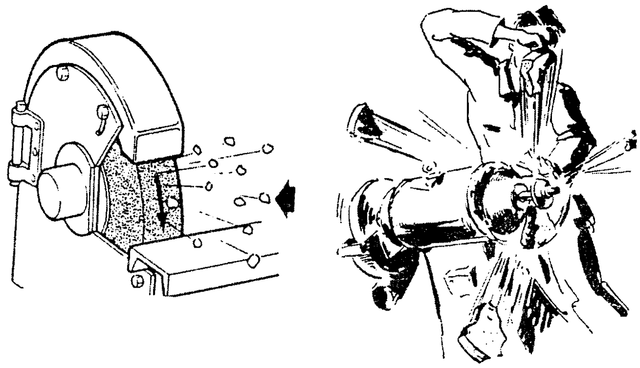

Fig. 1. The grinding tool breakage hazard

The grinding tool have nonhomogenous composition and it is very brittle, so that its breakage can happen, because of:

- excessive pressure or impact,
- too high circumferential velocity,
- irregular assembling,
- faulty technological selection and similar.

Faulty technological selection of the grinding wheel implies, that for grinding of working piece of high hardness, the "hard" grinding wheel is used. At grinding the materials of relatively high hardness, because of fast wear of cutting edges, the grinding wheel has less steadiness, at which "hard" grinding wheel becomes smoothed and the effect of grinding is decreased. If we want to increase the effect of grinding, it is necessary to provide higher pressure between the grinding wheel and the working piece. The mechanical loading is increased, and this is one of reasons for the grinding wheel breakage.

In the procedure of proper grinding of the working pieces consisted of hard material, it is necessary to use "soft" grinding wheel, and "hard" grinding wheel for softer metals, [1].

For evaluation of the rate of hazard, of possible grinding wheel breakage, the most important factors are:

- centrifugal force, and
- angle of safety guard opening around the grinding wheel.

Centrifugal force, which originates at the moment of the grinding wheel breakage, is defined by the expression:

$$F_c = \frac{m_1 \cdot V_c^2}{x_c} \cdot 10^3 \quad (1)$$

where are:

$m_1$ - mass of broken piece of the grinding wheel, in [kg],
$V_c$ - circumferential velocity of the grinding wheel, reduced in the center of a broken piece, in [m/s],
$x_c$ - the center of gravity of a broken piece of the grinding wheel, in [mm].

In order to prevent the uncontrolled bursting of pieces of the grinding wheel due to its breakage, the grinders must have the built-in safety guard. However, technological and exploitation reasons, are dictating the size and angle of the grinding wheel protective opening. Those sizes are mostly standardized, and they amount $60^o$; $90^o$, $120^o$ and $180^o$.

In case that the grinding wheel does not have the safety guard, it can be supposed that it will be broken into two parts. This is the most unfavourable case for the attendant, because the hazard is the highest then. However, if there is safety guard built-in round, the hazard for the operators will be less in case of breakage. There is no uncontrolled bursting of the grinding wheel parts in this case, but hazard should be expected from the direction of the safety guard opening.

For determination of the centrifugal force of the largest broken part of the grinding wheel, which passes through the safety guard opening, it is necessary for us to know its weight, velocity and center of gravity from the axis of rotation.

*The weight in the center of gravity* of the broken piece of the grinding wheel can be determined according to circumferential velocity in the moment of breakage of the grinding wheel ($V_w$) and diameter of the grinding wheel ($D$):

$$V_c = 2 \cdot V_w \cdot \frac{x_c}{D} \tag{2}$$

where are:
$x_c$- center of gravity of the broken part of the grinding wheel, in [mm],
$D$ - outside diameter of the grinding wheel, in [mm],
$V_w$ - circumferential velocity in the moment of the grinding wheel breakage, in [m/s].

*The center of gravity of the broken piece of the grinding wheel* can be approximately determined on the base of center of gravity of the segment of annulus. This center of gravity is defined as:

$$x_c = \frac{d}{3} \cdot \frac{\sin(\alpha/2)}{(\alpha/2)} \cdot \left( \frac{\psi^3 - 1}{\psi^2 - 1} \right) \tag{3}$$

where are: $d$ - inside section of the grinding wheel, in [mm],
$\psi$ - the ratio between inside and outside section of the grinding wheel,
$\alpha$ - the angle of the safety guard grinding wheel opening.

By substitution of the expression (2) and (3) in the expression (1), the derived formula of the centrifugal force is obtained:

$$F = m_1 \cdot k_1 \cdot \frac{V_w^{\ 2}}{\psi} \left( \frac{\psi^3 - 1}{\psi^2 - 1} \right) \cdot 10^3 \tag{4}$$

where are: $k_1 = \frac{1}{6} \cdot \frac{\sin(\alpha/2)}{(\alpha/2)}$ - constant for determined angle of safety guard opening.

## 3. THE RISK OF HAZARD OF THE GRINDING TOOL BREAKAGE

Safety of operators, and their endangerment during machine attendance, are two different occurrences. According to probability of origin, these occurrences are opposite, so the origin of one is excluding the occurrence of the other. On the base of this exclusivity, it can be accepted that rate of safety (prevention) and rate of endangerment (hazard), are presenting two probabilities of occurrences, which sum is equal to unit.

For determination of the risk of hazard, of the grinding tool breakage it is necessary to be acquainted with the centrifugal force of the broken piece of the grinding wheel and the angle of the safety guard opening round the grinding wheel. Taking into consideration, that hazard occurrence (that is the risk ($R_h$), and the safety occurrences ($S_o$), are two independent occurrences ($R_h + S_o$) = 1, and their relation can be defined, according to the following mathematical model:

$$R_h = 1 - \frac{1}{1 + a^i \cdot 2^k} \tag{5}$$

where are: $a$ - parameter which express the basic characteristic of hazard,
$i$ - the hazard intensity,
$k$ - the range of hazard effect.

The risk of hazard ($R_h$) depending on influence parameters ($a,i,k$), can vary in the range of zero to one, $R_h \in (0 \div 1)$.

For the hazard risk analyzing, and for determining the safety rate, two cases can be observed:

In the first case, if limit value:

$$\lim_{a \to 0} \frac{1}{1 + a^i \cdot 2^k} \to 1 \tag{6}$$

gravitates towards number one, according to the expression (5) the risk of hazard tends to zero ($R_h \to 0$). In this theoretical case, the risk of hazard is minimal, while the safety rate is maximal ($S_o \to 1$). This means that safety rate can be observed according to the expression:

$$S_o = \frac{1}{1 + a^i \cdot 2^k} \tag{7}$$

In the second case, if limit value:

$$\lim_{a \to \infty} \frac{1}{1 + a^i \cdot 2^k} \to 0 \tag{8}$$

gravitates towards zero, than according to the expression (5) the risk of hazard tends to the maximal value ($R_h \to 1$), while the safety rate is minimal ($S_o \to 0$).

In dependence of grinding wheel circumferential velocity, the angle of the safety guard opening and the centrifugal force of the broken piece of the grinding wheel, the parameters ($a$), ($i$), and ($k$) are defined, and they are important for determination the rate of hazard, by the given mathematical model (5).

**The parameter (*a*)** expresses the basic characteristic of hazard and in this case it represents the relation between circumferential velocity at the moment of breakage ($V_w$) and admissible velocity of the grinding wheel ($V_g$), this is $a = V_w / V_g < 1$.

**The parameter (*i*)** defines the intensity of hazard, and in this case it presents the relation between the safeguarded ($A_s$) and unguarded ($A_u$) part of the grinding wheel, that is $i = A_s / A_u$. This parameter, in a theoretical case, is ranging in limits from zero to infinity, if the grinding wheel is unguarded ($A_s = 0$; $A_u = 1$) the intensity of hazard is zero ($i$=0). If the grinding wheel is completely safeguarded (completely guarded $A_u = 1$; $A_u = 0$) the intensity of hazard is infinite ($i \rightarrow \infty$). In the practice, this parameter is ranging between these two theoretical extreme values ($i = 1$, for angle $\alpha = 180^0$; $i = 5$, for the angle $\alpha = 60^0$; $A_s = R^2 (\pi - \alpha)$, $A_u = R^2(\alpha/2)$.

**The parameter (*k*)** defines the range of hazard effect. In regard of realizing of possible hazards of grinding tool breakage, this parameter presents in which space and distance from grinder, a risk of operator's injuring is possible. For example, there is a risk of grinding wheel hazard in the distance of 5 meters.

According to the adopted range of the hazard effect ($k$) and the hazard intensity ($i$), the risk of hazard ($R_h$) is estimated, and its values are given in the tables below (1, 2) and in the constructed diagrams (figs. 2, 3).

Table 1. Values of the risk of hazard (for intensity of adopted safety, $i = 1$)

| Range of hazard effect ($k$) | Basic characteristic of hazard (a) | | | | | |
|---|---|---|---|---|---|---|
| | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 | 1,0 |
| 0,0 | 0,33 | 0,37 | 0,41 | 0,44 | 0,47 | 0,50 |
| 0,5 | 0,41 | 0,46 | 0,50 | 0,53 | 0,56 | 0,59 |
| 1,0 | 0,50 | 0,54 | 0,58 | 0,61 | 0,64 | 0,67 |
| 1,5 | 0,59 | 0,63 | 0,66 | 0,69 | 0,72 | 0,74 |
| 2,0 | 0,67 | 0,71 | 0,74 | 0,76 | 0,78 | 0,80 |
| 2,5 | 0,74 | 0,77 | 0,80 | 0,82 | 0,84 | 0,85 |
| 3,0 | 0,80 | 0,83 | 0,85 | 0,86 | 0,88 | 0,89 |
| 3,5 | 0,85 | 0,87 | 0,89 | 0,90 | 0,91 | 0,92 |
| 4,0 | 0,89 | 0,91 | 0,92 | 0,93 | 0,94 | 0,94 |
| 4,5 | 0,91 | 0,93 | 0,94 | 0,95 | 0,95 | 0,96 |
| 5,0 | 0,94 | 0,95 | 0,96 | 0,96 | 0,97 | 0,97 |

Table 2. Values of the risk of hazard (for intensity of adopted safety $i$ =5)

| Range of hazard effect ($k$) | Basic characteristic of hazard (a) | | | | | |
|---|---|---|---|---|---|---|
| | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 | 1,0 |
| 0,0 | 0,03 | 0,07 | 0,14 | 0,25 | 0,37 | 0,50 |
| 0,5 | 0,04 | 0,10 | 0,19 | 0,32 | 0,45 | 0,59 |
| 1,0 | 0,06 | 0,13 | 0,25 | 0,40 | 0,54 | 0,67 |
| 1,5 | 0,08 | 0,18 | 0,32 | 0,48 | 0,62 | 0,74 |
| 2,0 | 0,11 | 0,24 | 0,40 | 0,57 | 0,70 | 0,80 |
| 2,5 | 0,55 | 0,30 | 0,49 | 0,65 | 0,77 | 0,85 |
| 3,0 | 0,20 | 0,38 | 0,57 | 0,72 | 0,82 | 0,89 |
| 3,5 | 0,26 | 0,47 | 0,65 | 0,79 | 0,87 | 0,92 |
| 4,0 | 0,33 | 0,55 | 0,73 | 0,84 | 0,90 | 0,94 |
| 4,5 | 0,41 | 0,64 | 0,79 | 0,88 | 0,93 | 0,96 |
| 5,0 | 0,50 | 0,71 | 0,84 | 0,91 | 0,95 | 0,97 |

From the diagram (fig. 2) can be seen, that for the range of hazard effect ($k = 0$) and the basic characteristic of hazard ($a = 1$), the limit value of the risk of hazard is $R_h = 0{,}5$.

The adopted rate of safety also has the value ($S_o = 0,5$). This is the case when we do not know the final result. So, if basic characteristic of hazard is known ($a$) and also the range of hazard effect ($k$), the risk of hazard can be estimated very easily.

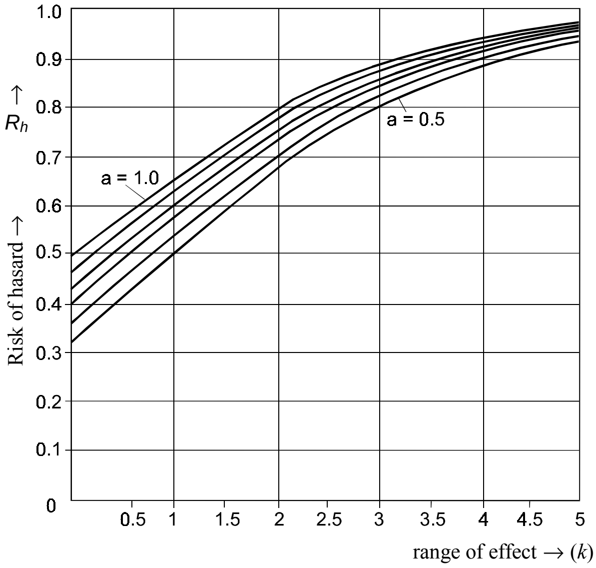


Fig. 2. Risk of hazard dependence from range of effect; $i = 1$)

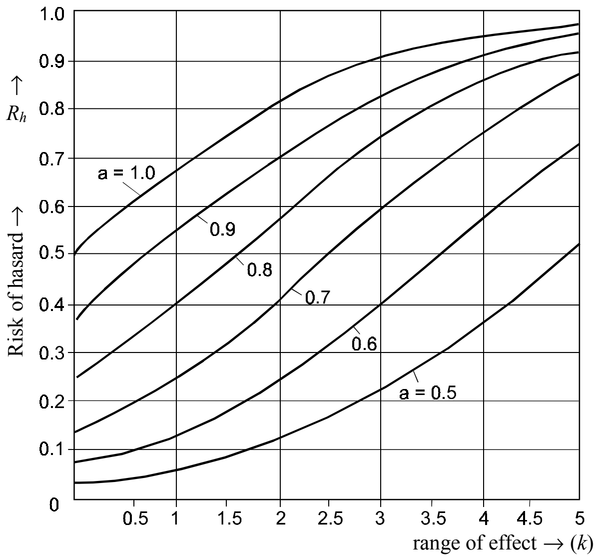


Fig. 3. Risk of hazard dependence from range of effect; $i = 5$)

## 4. CONCLUSION

According to analysis given in this work, we can state following:

- Determination of the risk of hazard is related only to hazards created as a result of unsatisfactory mechanical safety, of those parts of machine, which can cause the operator's injuring.
- Suggested mathematical model for determination the of hazard risk, is tested on a sample on the grinding wheel breakage and bursting of a workshop grinder. For this case the risk of hazard mostly depends on circumferential velocity which causes the grinding wheel breakage, and on the originating centrifugal force of the broken piece of the grinding wheel.
- Evaluation of the risk of the grinding tool breakage, is that, because by the suggested mathematical model the risk of hazard injuring can be determined, and also the objective estimate about applied measures of the mechanical safety at the workshop grinder is given.

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# RIZIK PRI LOMU ALATA ZA BRUŠENJE

**Žarko Janković**

*U radu su definisani parametri za odredjivanje stepena opasnosti od mogućeg loma alata za brušenje. Za odredjivanje ovog stepena dat je odgovarajući matematički model. Potvrda valjanosti ovog modela analizirana je na primeru loma alata za brušenje kod radioničke brusilice.*

Ključne reči: *rizik opasnosti, stepen zaštite, alat za brušenje*