Abstract:
The mining organ of the longwall heading machine KGS-320 with radial tools was the subject of the analysis. Cooperation of single knife with the mined solid rock was estimated in order to determine values of the forces and moments that might occur in the mining process and to estimate the energy consumption of the mining process. Analogous determination of forces and moments values as well as energy consumption of the mining process for the whole mining organ with regard to all the knives installed.

Following the thorough analysis of the solid rock mining process with the longwall tumble heading machine mining head the PC computer program simulating such organ’s mode of action has been developed. This program presents the simulation of the mining process in the part regarding direct contact of the cutting tool (knife) with the rock mass.

The result of this simulation is force and moments distribution, which are transmitted via the mining organ (head) during one full turn (360°) and, as consequence, via whole longwall heading machine.

INTRODUCTION

Poland’s access to the United Europe’s markets requires economic and technical improvement also in the coal mining industry with broader search for more effective methods allowing higher output concentration and lower costs level resulting in positive accumulation [7, 9, 13].

In Polish mining industry coal exploitation takes place mainly by wall systems via mechanical mining with the use of longwall tumble heading machines. The increase in coal output in mines is correlated with mining range expansion with already existing tumble heading machines to hard mined coals [3].

The development of coal mining mechanization is mainly directed by:
- high output concentration,
- working place reduction,
- increase in economic efficiency of production.

Technical development of mechanical mining machines (longwall tumble heading machines) as well as their application in given conditions has already been solved, and the mining process with the use of these machines is more effective than other methods. Other, unconventional mining methods where the processes take place in laboratory or semi-industrial conditions bring unsatisfactory results due to high energy consumption or technical difficulties in given mining conditions [2, 5]. Then, it can be stated that mechanical mining will dominate Polish and world mining industry.

In order to face the progress and economic conditions the effectiveness of mechanical mining machines’ utilization should increase by:
- decrease of energy consumption of the mining process,
- increase of tools’ and mining organs’ durability and reliability,
- improvement of energy transmission from the engine to the mining organ,
- automation of the mining process,
- improvement of operators’ safety and working conditions.

Constant development of coal layers’ mining mechanization, application of tumble heading machines with various mining heads and increasing power installed require the classification and evaluation of coal seams with regard to their mineability. This would allow for proper selection of mining machines to given mining conditions and technological forecasting of energy consumption of the mining process i.e. power demand.

Therefore the need of constant improvement of research means and methods leading to determination of total mined coal material’s resistances during its disintegration, i.e. to determination tumble heading machine’s power necessary to mine in given mining-geological conditions with pre-set advance speed.

BRIEF DESCRIPTION OF PROBLEM

In Polish mining industry mechanical excavation of coal seams with the use of longwall tumble coal miners is applied.

In order to consider the whole complexity of the problem the mining process should be regarded as interaction between the solid rock and the mining machine.
The mining, i.e. separation of coal pieces from the solid rock with the use of a knife or set of knives placed on the mining organ, is a result of composition of two tumble heading machine mining head’s motions – rotation and translation.

We assume that the main motion is rotation of the mining organ, defined as cutting velocity, while the translation of the whole longwall heading machine is a supporting motion. Independently from the exploitation system and mining-geological conditions three basic phases of organ’s action can be distinguished:
- phase I – normal work. The most often. The mining organ works with full web with constant mining height whereas the advance of the mining organ is a result of the longwall heading machine’s velocity,
- phase II – slotting. This is the preliminary mode of action of the mining machine taking place at the beginning of the mining cycle. In this case the advance velocity as well as the mining height are equal to normal mode whereas the working area of the mining machine varies from zero to maximum value,
- phase III – related to elevation or depression of the mining organ. It occurs during mining height modification. In this phase the longwall heading machine stands still while the arm translocation operator is activated.

It could be said that readily mined coals’ mining modes are depleted, and we have to face the problem of currently applied machinery readjustment to harder mineability conditions.

The mining conditions consist of:
- mining-geological conditions of strata deposition including mineability,
- placement and arrangement of cutting tools,
- tools’ shape and their cooperation,
- grindability,
- machines’ durability and reliability,
- energy consumption in the mining process.

The above are some of the factors (very vital though) characterizing the efficacy of the mechanical mining with the use of the longwall tumble coal miner.

Constant tendency to concentrate the excavation on one longwall leads to pile up of large amount of machines’ durability and reliability, tools’ shape and their cooperation, grinding, machines’ durability and reliability, energy consumption in the mining process.

The mining process study, especially in difficult mining-geological conditions have proved that in order to set the range of the tumble mining heading machines application the so called decisive coal properties should be defined.

Following Bialy [4, 5] and Borycz and Koziel [6] the decisive coal properties include:
- mineability, represented by mineability index $A_{mb}$, or $WU_{p b}$ kN/m,
- exploitation pressure represented by vertical component of the stress state $\sigma$, MPa,
- energy consumption of the mining process $E_{m}$ MJ/m$^3$.

The above properties determine the technique and technology of the exploitation process. These factors determine the mining productivity fundamentally by precisely the efficacy of the mining machines.

The construction and selection of the machines mining organs should be based upon the above factors.

MINING ORGANS OPERATION ANALYSIS

The machines applied in underground mining include:
- mechanical coal miners,
- heading machines,
- tunnel drivers.

The analysis of the mining machines organs of various constructions allows for arrangement and division of working geometry of these organs into four major groups:
- group I (Fig. 1a) – mechanical coal miners’ mining organs,
- group II (Fig. 1b) – mining organs of cutter gib heading machines with the mining organ rotating around the cutter gib’s axis and advance parallel to the cutter’s axis (type 1),
- group III (Fig. 1c) – mining organs of cutter gib heading machines with the mining organ rotating around the cutter gib’s axis and advance normal to the cutter’s axis (type 2),
- group IV (Fig. 1d) – tunnel drivers’ mining organs.

![Fig. 1 The mining machines organs of various constructions](image-url)
This paper presents the analysis of the group I mining organ’s – after Bialy [1, 2], and Vasek, Slavik and Gondek [14] – geometry of action, i.e. longwall tumble coal miner (Fig. 1a).

The heading machine is a team machine carrying out many operations simultaneously (mining and loading).

With regard to the longwall tumble coal miners (which are nowadays the only produced and applied) two basic types are distinguished:

- KWB type,
- KGS, KGE, KSW type.

This type of the mining organ may turn bi-directly (Fig. 2a), as well as advance in four directions (Fig. 2b,c).

The mining organ’s mode of action is defined as penetration of the organ, along with the knife placed on it, into the mined solid coal – the mining organ is winning different height ($m_{nt}$ varies from 0 to $D$).

Following cases are distinguished in this process:

- the mining organ starts the excavation on the web depth value 0 up to value $h$ (Fig. 3a,b),
- the mining organ is digging through one or more layers of different coal types or inclusions (Fig. 3c,d).

The mining process realized by the mining organ of the tumble coal miner is a process of separation of coal parts from the solid rock with the use of the cutting tools (knives). As a result of this operation we obtain slices as many as the amount of knives placed on the mining organ.

The slice with characteristic data as a result of one knife’s cut in tri-dimensional co-ordinate system is presented on Figure 4.

The height of the mined solid coal ($m_{nt}$, Fig. 3) varies from 0 to value D as the mining organ penetrates the solid coal rotating along its axis.

**ESTIMATION OF FORCE AND MOMENTS VALUES ON THE MINING HEAD**

The mining organ is getting the solid coal with the use of cutting tools – the knives placed on it.

Due to the fact, that the mining organ is the most important element in the process of selection of the longwall complex it is very important that it satisfies all requirements of the complex. The estimation of the force and moments values on the mining organ as well as their variability in the working mode (one full turn) is very important then.

The subject of this analysis is estimation of the values occurring during the longwall tumble coal miner KGS-320 mining organ’s action with radial knives placed on it. The cutting tools, called miner’s knives, are replaceable elements mounted in holders welded on the mining organ. When describing the knives placement geometry on the mining organ a set: knife- knife’s holder is considered.

The geometry of the mining organ of the longwall tumble coal miner (Fig. 5) is described by following parameters:

- the amount of knives on the mining organ - X pcs,
- the distance from the knife’s edge to the axis of the mining organ - R mm,
- the distance from the knife’s edge to the yz plane - x mm,
- the knife’s placement circumferential angle - $\phi^o$,
- the knife’s angle of rotation related to the drum’s (mining organ) axis - $\beta_1^o$,
- the knife’s angle of inclination - $\alpha_1^o$,
- the knife edge’s angle of rotation - $\gamma_1^o$,
- the knife’s length - 1 (one) mm.

The cooperation between single knife and the mined solid coal has been analyzed. Consequently, forces’ and moments’ values as well as mining head’s load (of the whole mining organ from all installed knives) was estimated. The longwall tumble coal miner’s mining head’s load means resultant forces and moments occurring on the mining head at one full turn (360°).

The forces resulting from rock mass reaction press (concentrated in one point) one knife of the mining organ, which is under influence of the load resulting from the rock mass reaction on blade’s penetration.
Three perpendicular forces describe the knife’s load (Fig. 6):
\( F_t \) – cutting force,
\( F_n \) – clamp force to the mined solid coal,
\( F_b \) – side (thrust) force.

The direction of \( F_t \) force overlaps the instantaneous direction of tangent to the motion path (cycloid) of knife’s blade edge. The \( F_n \) force direction is normal to \( F_t \) force direction and is consistent with direction of line connecting the knife’s blade edge to the beginning of the co-ordinate system, while the direction of \( F_b \) force is normal to the plane formed by \( F_t \) and \( F_n \) forces. The knife’s orientation is described by angle \( \phi \), while the inclination angle \( \beta_1 \) of knife’s edge in horizontal plane allows considering the solid rock’s reaction with helical plane of the mining organ (semi-axial force occurrence). All the components of resultant reaction of cutting force \( F_t \) have been considered, as well as the clamp force \( F_n \) resulting from incising of the mining head into the solid rock. This reaction is not related with the mining organ’s rotation therefore it has been accepted that component \( F_n \) of the force in relation to the helical plane of the mining organ.

During the longwall tumble coal miner mining organ’s action the solid coal is mined by given amount of knives. During one full turn of the mining head this amount varies as a result of entering and leaving the mined solid coal by given knives. Each entering knife deepening into the solid coal makes a cut.

The size and shape of the cut depend on:
- the properties of the mined coal,
- the situation of the cutting knife related to the preceding knife,
- coal miner’s parameters; the web, angular velocity of the mining head, advance speed, mining height.

The forces, as well as the moments operating on a single knife and on the whole mining organ in given planes are presented on Figures 6 and 7.

Forces values (Fig. 6) are as follows:
\[
F_t = \left( F_t^x; F_t^y; F_t^z \right) = \left( 0; -F_t \cos \phi; F_t \sin \phi \right) \tag{1}
\]
\[
F_n = \left( F_n^x; F_n^y; F_n^z \right) = \left( -F_n \sin \phi \sin \beta_1; -F_n \sin \phi \cos \beta_1; -F_n \cos \phi \sin \beta_1 \right) \tag{2}
\]
\[
F_b = \left( F_b^x; F_b^y; F_b^z \right) = \left( -F_b \cos \phi \sin \beta_1; F_b \sin \phi \sin \beta_1; -F_b \cos \phi \sin \beta_1 \right) \tag{3}
\]

In order to determine the forces moment’s values related to given axes of the system, the sum of all forces components related to given axes of the selected co-ordinate system needs to be determined.
Finally, the moments related to given axes are as follows:

\[ M_x = (F_t \sin \phi \sin \beta_1 + F_b \cos \beta_1) y - \]
\[ - (F_t \sin \phi - F_n \cos \phi \sin \beta_1 + F_b \cos \phi \sin \beta_1) z \]  
\[ M_y = (F_t \cos \phi - F_n \sin \phi \cos \beta_1 + F_b \sin \phi \cos \beta_1) x - \]
\[ -F_n \sin \phi \cos \beta_1 \]  
\[ M_z = (F_t \sin \phi - F_n \cos \phi \sin \beta_1 + F_b \cos \phi \sin \beta_1) x - \]
\[ -F_n \sin \phi \cos \beta_1 \]  

The forces and moments values which might occur on the mining head equipped with knives, equal the sum of forces and moments resulting from the load of all knives situated in a given moment in the mined coal. The above model of longwall tumble coal miner’s mining head’s loading and the method of forces and moments estimation is so complicated that its practical application requires special computer calculating program with computer operating system.

MINING PROCESS MODELLING

The requirements related with the mining organ’s operation make necessary finding of such tools that would make this process easier. Starting with the design process or selection from the already existing organs, the influence of many factors should be undertaken. Therefore, a very vital task is a possibility of quick selection of the proper organ, with regard to fast and easy check whether an organ would operate properly in given conditions. In order to reach this aim a specialist computer program has been developed, which allows estimating all previously established values.

After detailed analysis of the solid coal mining process with the use of the longwall tumble miner’s mining head a PC computer program simulating such organ’s mode of action has been developed. This program presents the simulation of the mining process in the part regarding direct contact of the cutting tool (knife) with the solid coal.

The result of this situation is a scheme of cutting and analysis of forces and moments that are transmitted by the mining organ (head) during its one full turn (360°) and consequently by the whole coal miner.

In order to present the forces and moments values occurring at one full turn of the coal miner’s head the mode of action of a single knife has been described.

The following are the results of the mining resistance overcoming:

- cutting force \( F_o \),
- clamping force to the mined solid coal \( F_{co} \),
- knife’s clamping force (passive pressure force) \( F_b \).

Composition of single knives forces and moments’ values leads to obtaining total forces and moments’ values of all the knives placed on the mining head. Obtained forces and moments values allow analyzing of the variable mode of action of the mining organ during its one full turn, i.e. the dynamics of the mining process. The actual web areas of given knives have also been determined presenting instantaneous pressures of the given knives during the mining process. The volume of the mined coal was determined as well which is the value strongly influencing the energy consumption of the mining process.

During mining process modeling following assumptions have been made:

- mining velocity \( v_r \), and advance speed \( v_p \) are constant \((k = \text{const})\),
- mining organ operates on the full height \( H \), which is allowed by its construction,
the mined coal over the whole height and length of the longwall is homogenous (is characterized by the constant value of the mineability index A).

**CALCULATIONS RESULTS**

With the application of the developed simulating program the scheme of mining with the use of the mining head of KGS–320 coal miner at its one full turn (360°) was presented.

Table 1 presents the data resulting from the longwall tumble coal miner’s mining organ’s geometry (with respect to description in chapter 4).

To perform the calculations following parameters of the coal miner have been accepted;

- Knives type – radial – RAPID 83/3, quantity 38,
- Knife’s width 20 mm, knife’s radius 22 mm,
- Mineability index \( A_0 = 3.36 \) kN/m,
- Side-crumble angle \( \psi = 60^\circ \),
- Mining organ’s diameter \( H = 1446 \) mm,
- Web depth – 650 mm,
- Mining head’s rotational speed \( v_r = 40 \) cycles/min
- Coal miner’s advance speed \( v_p = 3 \) m/min.

**Table 1**

<table>
<thead>
<tr>
<th>Knife No</th>
<th>R</th>
<th>X</th>
<th>( \phi^o )</th>
<th>( \beta^o )</th>
<th>Knife placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>795</td>
<td>54</td>
<td>31</td>
<td>-15</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>785</td>
<td>28</td>
<td>48</td>
<td>-27</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>770</td>
<td>0</td>
<td>65</td>
<td>-42</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>795</td>
<td>115</td>
<td>82</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>795</td>
<td>54</td>
<td>117</td>
<td>-15</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>785</td>
<td>28</td>
<td>135</td>
<td>-27</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>770</td>
<td>0</td>
<td>155</td>
<td>-42</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>800</td>
<td>87</td>
<td>171</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>795</td>
<td>54</td>
<td>211</td>
<td>-15</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>785</td>
<td>28</td>
<td>226</td>
<td>-27</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>770</td>
<td>0</td>
<td>245</td>
<td>-42</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>800</td>
<td>87</td>
<td>262</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>795</td>
<td>115</td>
<td>297</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>785</td>
<td>28</td>
<td>315</td>
<td>-27</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>770</td>
<td>0</td>
<td>333</td>
<td>-42</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>800</td>
<td>87</td>
<td>351</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>800</td>
<td>160</td>
<td>28</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>800</td>
<td>250</td>
<td>47</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>800</td>
<td>340</td>
<td>66</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Mining organ’s diameter \( H = 1446 \) mm,
- Web depth – 650 mm,
- Mining head’s rotational speed \( v_r = 40 \) cycles/min
- Coal miner’s advance speed \( v_p = 3 \) m/min.

Knives’ placement:

- 0 – cutting disk,
- 1, 2, 3, 4 – consecutive helical lines on the longwall tumble coal miner’s mining head.

With regard to the method and algorithm of calculations pre-set the scheme of cutting forces and moments course on the mining organ during its one full turn (360°) was estimated (Table 2, 3, 4, Fig. 8 to 11).

Following have also been estimated:

- web areas of given knives,
- loosening line’s length for given knives,
- mined volume \( V \) at one full turn.
- mean values of forces and moments during one full turn (360°).
### Table 2
Web areas and loosening lines' length of the knives

<table>
<thead>
<tr>
<th>Knife No.</th>
<th>Web area mm²</th>
<th>Loosening line length mm</th>
<th>Knife No.</th>
<th>Web area mm²</th>
<th>Loosening line length mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1510</td>
<td>126</td>
<td>20</td>
<td>1742</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>802</td>
<td>99</td>
<td>21</td>
<td>1702</td>
<td>82</td>
</tr>
<tr>
<td>3</td>
<td>155</td>
<td>34</td>
<td>22</td>
<td>4727</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>842</td>
<td>73</td>
<td>23</td>
<td>1624</td>
<td>81</td>
</tr>
<tr>
<td>5</td>
<td>1708</td>
<td>134</td>
<td>24</td>
<td>1358</td>
<td>78</td>
</tr>
<tr>
<td>6</td>
<td>828</td>
<td>99</td>
<td>25</td>
<td>1703</td>
<td>83</td>
</tr>
<tr>
<td>7</td>
<td>163</td>
<td>38</td>
<td>26</td>
<td>1681</td>
<td>82</td>
</tr>
<tr>
<td>8</td>
<td>1414</td>
<td>115</td>
<td>27</td>
<td>1682</td>
<td>83</td>
</tr>
<tr>
<td>9</td>
<td>1532</td>
<td>125</td>
<td>28</td>
<td>1692</td>
<td>82</td>
</tr>
<tr>
<td>10</td>
<td>719</td>
<td>94</td>
<td>29</td>
<td>1337</td>
<td>79</td>
</tr>
<tr>
<td>11</td>
<td>162</td>
<td>36</td>
<td>30</td>
<td>1804</td>
<td>84</td>
</tr>
<tr>
<td>12</td>
<td>1137</td>
<td>96</td>
<td>31</td>
<td>1643</td>
<td>85</td>
</tr>
<tr>
<td>13</td>
<td>663</td>
<td>96</td>
<td>32</td>
<td>1700</td>
<td>82</td>
</tr>
<tr>
<td>14</td>
<td>1893</td>
<td>134</td>
<td>33</td>
<td>1689</td>
<td>82</td>
</tr>
<tr>
<td>15</td>
<td>163</td>
<td>38</td>
<td>34</td>
<td>1735</td>
<td>84</td>
</tr>
<tr>
<td>16</td>
<td>1238</td>
<td>110</td>
<td>35</td>
<td>4651</td>
<td>169</td>
</tr>
<tr>
<td>17</td>
<td>1735</td>
<td>85</td>
<td>36</td>
<td>1582</td>
<td>83</td>
</tr>
<tr>
<td>18</td>
<td>1654</td>
<td>81</td>
<td>37</td>
<td>1736</td>
<td>83</td>
</tr>
<tr>
<td>19</td>
<td>1651</td>
<td>83</td>
<td>38</td>
<td>1697</td>
<td>82</td>
</tr>
</tbody>
</table>

### Table 3
Forces values at tumble turn by 360°

<table>
<thead>
<tr>
<th>Rotation angle °</th>
<th>F&lt;sub&gt;x&lt;/sub&gt; N</th>
<th>F&lt;sub&gt;y&lt;/sub&gt; N</th>
<th>F&lt;sub&gt;z&lt;/sub&gt; N</th>
<th>Rotation angle °</th>
<th>F&lt;sub&gt;x&lt;/sub&gt; N</th>
<th>F&lt;sub&gt;y&lt;/sub&gt; N</th>
<th>F&lt;sub&gt;z&lt;/sub&gt; N</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>42.85</td>
<td>788.74</td>
<td>385.91</td>
<td>190</td>
<td>74.15</td>
<td>947.06</td>
<td>627.05</td>
</tr>
<tr>
<td>20</td>
<td>54.24</td>
<td>753.75</td>
<td>429.51</td>
<td>200</td>
<td>63.07</td>
<td>917.19</td>
<td>570.39</td>
</tr>
<tr>
<td>30</td>
<td>49.14</td>
<td>811.55</td>
<td>445.59</td>
<td>210</td>
<td>58.79</td>
<td>896.91</td>
<td>534.29</td>
</tr>
<tr>
<td>40</td>
<td>58.61</td>
<td>753.37</td>
<td>482.17</td>
<td>220</td>
<td>58.79</td>
<td>925.83</td>
<td>532.76</td>
</tr>
<tr>
<td>50</td>
<td>65.89</td>
<td>796.99</td>
<td>541.69</td>
<td>230</td>
<td>56.57</td>
<td>925.45</td>
<td>508.36</td>
</tr>
<tr>
<td>60</td>
<td>74.48</td>
<td>848.63</td>
<td>586.37</td>
<td>240</td>
<td>53.62</td>
<td>872.02</td>
<td>474.02</td>
</tr>
<tr>
<td>70</td>
<td>82.30</td>
<td>844.33</td>
<td>608.85</td>
<td>250</td>
<td>48.77</td>
<td>876.65</td>
<td>455.86</td>
</tr>
<tr>
<td>80</td>
<td>86.59</td>
<td>911.92</td>
<td>644.79</td>
<td>260</td>
<td>52.92</td>
<td>923.80</td>
<td>484.82</td>
</tr>
<tr>
<td>90</td>
<td>78.49</td>
<td>822.55</td>
<td>610.43</td>
<td>270</td>
<td>51.50</td>
<td>931.28</td>
<td>476.41</td>
</tr>
<tr>
<td>100</td>
<td>78.97</td>
<td>823.12</td>
<td>618.03</td>
<td>280</td>
<td>51.78</td>
<td>919.13</td>
<td>452.65</td>
</tr>
<tr>
<td>110</td>
<td>78.38</td>
<td>803.06</td>
<td>612.43</td>
<td>290</td>
<td>45.76</td>
<td>863.64</td>
<td>390.71</td>
</tr>
<tr>
<td>120</td>
<td>78.46</td>
<td>759.89</td>
<td>609.91</td>
<td>300</td>
<td>43.55</td>
<td>853.05</td>
<td>372.93</td>
</tr>
<tr>
<td>130</td>
<td>80.76</td>
<td>787.51</td>
<td>646.16</td>
<td>310</td>
<td>43.75</td>
<td>823.88</td>
<td>364.82</td>
</tr>
<tr>
<td>140</td>
<td>87.37</td>
<td>827.77</td>
<td>712.65</td>
<td>320</td>
<td>43.52</td>
<td>834.18</td>
<td>370.95</td>
</tr>
<tr>
<td>150</td>
<td>85.58</td>
<td>862.50</td>
<td>697.19</td>
<td>330</td>
<td>44.10</td>
<td>812.45</td>
<td>371.69</td>
</tr>
<tr>
<td>160</td>
<td>83.59</td>
<td>893.70</td>
<td>700.62</td>
<td>340</td>
<td>50.61</td>
<td>846.27</td>
<td>416.66</td>
</tr>
<tr>
<td>170</td>
<td>79.76</td>
<td>948.19</td>
<td>688.09</td>
<td>350</td>
<td>51.80</td>
<td>862.26</td>
<td>431.16</td>
</tr>
<tr>
<td>180</td>
<td>78.31</td>
<td>955.54</td>
<td>672.46</td>
<td>360</td>
<td>42.75</td>
<td>784.32</td>
<td>381.25</td>
</tr>
</tbody>
</table>
Determination of workloads in cutting head of longwall tumble heading machine

**Fig. 8** Knives placement on the longwall tumble coal miner’s KGS-320 mining head during its one full turn (360°)

**Fig. 9** Mining scheme (knives web) at tumble turn by 360°

**Table 4**

<table>
<thead>
<tr>
<th>Rotation angle °</th>
<th>$M_x$ Nm</th>
<th>$M_y$ Nm</th>
<th>$M_z$ Nm</th>
<th>Rotation angle °</th>
<th>$M_x$ Nm</th>
<th>$M_y$ Nm</th>
<th>$M_z$ Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>518.13</td>
<td>61.50</td>
<td>184.77</td>
<td>190</td>
<td>708.00</td>
<td>184.17</td>
<td>217.30</td>
</tr>
<tr>
<td>20</td>
<td>529.15</td>
<td>78.68</td>
<td>168.16</td>
<td>200</td>
<td>669.54</td>
<td>163.10</td>
<td>211.96</td>
</tr>
<tr>
<td>30</td>
<td>562.10</td>
<td>76.51</td>
<td>183.11</td>
<td>210</td>
<td>649.49</td>
<td>154.82</td>
<td>210.40</td>
</tr>
<tr>
<td>40</td>
<td>563.68</td>
<td>82.86</td>
<td>150.32</td>
<td>220</td>
<td>673.41</td>
<td>142.04</td>
<td>210.20</td>
</tr>
<tr>
<td>50</td>
<td>615.62</td>
<td>102.08</td>
<td>166.68</td>
<td>230</td>
<td>668.33</td>
<td>118.68</td>
<td>200.76</td>
</tr>
<tr>
<td>60</td>
<td>644.99</td>
<td>129.61</td>
<td>185.90</td>
<td>240</td>
<td>621.43</td>
<td>101.76</td>
<td>184.39</td>
</tr>
<tr>
<td>70</td>
<td>645.99</td>
<td>145.50</td>
<td>194.68</td>
<td>250</td>
<td>602.22</td>
<td>94.06</td>
<td>199.39</td>
</tr>
<tr>
<td>80</td>
<td>681.22</td>
<td>167.97</td>
<td>227.29</td>
<td>260</td>
<td>635.47</td>
<td>87.61</td>
<td>204.44</td>
</tr>
<tr>
<td>90</td>
<td>638.04</td>
<td>178.50</td>
<td>209.45</td>
<td>270</td>
<td>631.09</td>
<td>77.52</td>
<td>198.06</td>
</tr>
<tr>
<td>100</td>
<td>647.29</td>
<td>183.97</td>
<td>209.75</td>
<td>280</td>
<td>606.93</td>
<td>65.20</td>
<td>194.47</td>
</tr>
<tr>
<td>110</td>
<td>635.53</td>
<td>180.85</td>
<td>192.79</td>
<td>290</td>
<td>537.98</td>
<td>49.01</td>
<td>185.83</td>
</tr>
<tr>
<td>120</td>
<td>623.44</td>
<td>174.12</td>
<td>173.91</td>
<td>300</td>
<td>516.60</td>
<td>49.36</td>
<td>191.32</td>
</tr>
<tr>
<td>130</td>
<td>654.11</td>
<td>182.15</td>
<td>174.72</td>
<td>310</td>
<td>499.52</td>
<td>45.63</td>
<td>186.67</td>
</tr>
<tr>
<td>140</td>
<td>704.32</td>
<td>206.58</td>
<td>188.99</td>
<td>320</td>
<td>509.04</td>
<td>47.57</td>
<td>185.71</td>
</tr>
<tr>
<td>150</td>
<td>726.60</td>
<td>205.91</td>
<td>197.81</td>
<td>330</td>
<td>507.12</td>
<td>49.52</td>
<td>176.49</td>
</tr>
<tr>
<td>160</td>
<td>740.53</td>
<td>218.42</td>
<td>209.94</td>
<td>340</td>
<td>548.79</td>
<td>56.27</td>
<td>181.94</td>
</tr>
<tr>
<td>170</td>
<td>754.82</td>
<td>213.58</td>
<td>224.94</td>
<td>350</td>
<td>569.67</td>
<td>61.60</td>
<td>192.89</td>
</tr>
<tr>
<td>180</td>
<td>746.29</td>
<td>203.86</td>
<td>224.01</td>
<td>360</td>
<td>511.24</td>
<td>63.85</td>
<td>182.94</td>
</tr>
</tbody>
</table>
The placement of the knives on the cutting disk is an unde-
loadable problem. The performed analysis should be used to
place the knives with the mined solid coal would be avoided (Fig.
10). The result of the performed analysis is a conclusion that
the highest differences in the web areas (Table 2). The vital problem is proper transition from the knives placement on the cutting disk to given snail’s lobes in such way that any fragment of the solid coal would not be mined with any knife placed on the cutting disk. It does also influence the non-uniform knives wear during the min-
ing process, with the costs accompanying, and the dy-
nameics of the whole mining process, too,

- determinate the forces and moments characteristics
during the mining process. Forces and moments re-
sulting from: the knife’s placement on the mining
organ, mineability index A value and side-crumble
angle $\varphi$ of the mined coal, have a strong influence on
the mining organ action’s dynamics also - the whole
col coal miner’s unstable performance.

The forces and moments characteristics of the longwall
tumble coal miner’s mining organ during its one full turn are presented on figures 11 and 12. The analysis of the curves $(F_x, F_y, F_z, M_x, M_y, M_z)$ shows further mining organ’s lacks. At one full turn of the mining organ (360$^\circ$) the vari-
babilities of forces and moments values show strong aberrations from the mean values, consequently $F_x$ forces varies from 42.75 N to 87.37 N, $F_y$ from 753.37 N to 955.54 N, while $F_z$ reaches values between 364.82 N and 712.65 N (Table 3). The moments vary within the following ranges: $M_x$ from 507.12 Nm to 754.82 Nm, $M_y$ from 45.63 Nm to 218.42 Nm and $M_z$ between 150.32 Nm and 227.29 Nm (Table 4).

Theses values show the dynamics of the longwall tum-
bler coal miner’s mining head’s load as well as the whole
machine.

The result of the performed analysis is a conclusion that
there are several lacks in the knives placement on the mini-
ing organs – regarding the coal miner’s dynamics of action
the solutions are imperfect.

The solution of the stated problem is a situation where
all forces and moments would vary as little as possible from
the mean values – the mining organ’s action would be sta-
able what has a direct relation to coal miner’s mining dyna-
(mining process).

REFERENCES


B. Drzęźla. „Dlaczego siedem dni w tygodniu?” in Trybuna Górnicza, 32(413)/2002.


