Mode I Stress Intensity Factors for Surface Planar Cracks in Circular Bodies Under Rotary Bending

Roman Król* and Paweł Grabowski†

Warsaw University of Technology
Institute of Construction Machinery Engineering

Abstract
A method of calculating stress intensity factors, using point-load weight function, for two-dimensional surface cracks subjected to rotary bending, applied to circular objects is described in the paper. The research has regarded planar cracks in finite circular bodies, which may occur e.g. in shaft cross sections of belt-driven machines. This type of drive is widely spread in the technological lines, therefore the research on improving its fatigue durability is crucial for development of this branch of industry. One of a few advantages of the method which has been applied is the possibility to evaluate stress intensity factor (SIF) values precisely in a quick and simple way. The paper shows the computation for various parameters of shape and size of shafts and cracks. The presented method usually yields conservative results compared to reference values obtained for the same configurations with the finite element method, which gives a good perspective to use such calculated SIFs for life assessment. Checking of these possibility is an essential issue of the work described in the paper.

Keywords: stress intensity factor, weight function, rotary bending, fatigue crack growth.

1 Introduction
The paper presents preliminary analysis and verification of the possibility of using two-dimensional weight function (WF2D) to determine stress intensity factors (SIFs) for circularly-shaped elements with two-dimensional crack on its surface. This would be very helpful in growth calculations of such cracks and assessment of the sustainability of circular parts of machine. Engineering practice reveals that such type of fatigue failure may be observed in shafts of belt-driven machines, (e.g. bucket elevators), fans or similar machines. The amount of such parts used in the industry is significant, and their durability is of great importance in maintaining the continuity of production process.

*roman.krol@simr.pw.edu.pl
†pawel.grabowski@simr.pw.edu.pl
Fatigue degradation consists of two stages - the first one is the initial stage, when crack cannot be detected directly and it occurs physically at the end of the stage. The second is the stage of its stable growth, when crack is physically detectable and increases its dimensions. When the second stage is considered, there are two main parameters, which are essential for fatigue resource assessment - these are actual dimensions of the crack and stress intensity factors at the front of the crack. SIF is the parameter, which richly describe an exertion of material at the crack front. Having known its value one is able to evaluate the rate of growth and predict time to obtain critical dimensions of crack, after which brittle fracture may occur in the element. One of the most popular methods used for analyses, when fatigue of material is considered, are numerical methods, e.g. the finite element method (FEM) or boundary element method (BEM), which require sophisticated software, engineering and analytical experience, and appropriate hardware. Even though analyses are very time-consuming. As an alternative for those methods, it seems to be, the method of two-dimensional weight function (WF2D) (Jankowiak, 2007; Glinka and Reinhardt, 2000), which enables calculation of SIF at any point of the crack contour. One of the most important advantages is that the method allows to overcome the basic problems of fatigue crack growth analysis such as arbitrary crack shape, arbitrary cross-section shape containing the crack and arbitrary stress distribution.

The analysis was performed for the initial semi-elliptical crack, located at the external contour of the circular cross-section (surface crack) under rotary bending. Operating conditions of real shafts correspond well to this stress distribution and obtained results are supposed to have acceptable accuracy. In the real roller such cracks can initiate at the bearing fillet or at the groove junction due to stress concentration. Initiation of fatigue damage process can be also caused by corrosion. Under normal operating conditions, these roller elements are loaded by rotary bending. However, the propagating crack grows while stress is tensile, should be taken into account appropriately to the crack position in the plane during rotation. Difficulty of measurement and record the actual operating loads of the part compels the use of calculations, which will help in analysing and predicting crack growth and part durability.

The analysis concentrates on calculation of the stress intensity factor for the defined surface crack in elements with circular-shaped cross-section undergoing rotary bending. As SIF is the most important parameter during fatigue analyses, therefore validation of SIF values with reference (Murakami, 1987) also had to be done, in order to determine if the results are reliable.

2 Model of element with crack

For purposes of this paper, the model had been assumed to be idealized shaft undergoing bending loading only. Such assumption is accurate for considered types of machine elements (e.g. non-driven shafts of bucket elevators, where torsion is neg-
ligible). Such assumption is also necessary to enable SIFs verification according to reference data, which are developed for I mode of loading (tensile loading).

Due to these, the model assumed to be the circular cross-section of the shaft, with a surface, semi-elliptic, fatigue crack on its external contour. The shaft rotates in the fixed stress field, which simulates rotary bending conditions. It is a non-uniform, triangularly-shaped tensile-compressive loading, with $\sigma = 0$ [MPa] at the centre of shaft (Fig.1). Such loading conditions cause cyclic changes of stress from $-\sigma_{\text{max}}$ to $\sigma_{\text{max}}$, which corresponds to bending shaft orthogonally to cross-section. When crack passes the neutral axis, tensile loading changes into compressive loading, however, because of fatigue phenomena character, only the tensile loading may cause crack growth ($\text{SIF} > 0$).

![Fig. 1. Stress distribution in shaft cross-section under rotary bending.](image-url)

Specific feature of the two-dimensional weight function method, used for calculations, is the fact that it requires real crack and body (element cross-section) contour to be replaced by rectilinear segments corresponding to actual contour. Due to technical requirements of an algorithm of WF2D [Reinhardt and Glinka 1997] program, used for calculation of stress intensity factors $K_I$ values, whole surface crack should adhere to body segment coinciding with $y$ axis of Cartesian coordinate system. For surface crack it used to be the bottom edge of the section. In some particular cases these features might be some limitations of the method e.g. while modelling rotary bending, it implies two types of conditions, to do it appropriately.

First one subordinates maximum crack width from number of body division segments. When approximation of circular element with usage of regular polygon is considered, it means that the number of segments must be selected, so that length of each segment is greater than width of assumed crack. Modelling larger cracks requires dividing body contour onto lower number of segments, which may effect onto accuracy of results. Nevertheless, usage of the software when cracks are quite large comparing to element radius, may be significantly limited (limited value of $2a/r$ ratio).

The second limitation of WF2D method and its numerical procedure, resulting
from above mentioned feature is lack of possibility to change easily location of the

crack in the body, which may result in some difficulties to simulate rotation of shaft

in stress field. It determines necessity to simulate the rotation of stress-field around

fixed element cross-section. Due to the fact, previous determination of stress field

corners’ coordinates, as well as stress values in those points is required. According to

the necessity of automatization of those geometrical calculations, additional external

procedure for the program had to be done. Data generated by the procedure may be

easily used as an input for the WF2D program (Reinhardt and Glinka [1997]), which

significantly reduces time to prepare the model.

3 The results of SIF and their verification

In order to know if WF2D method may be applied for the calculation of SIF values

and for analyzes of cracks’ growth in body which undergoes rotary bending, it should

be done some validation of results. For this reason SIF values at the front of fatigue

crack (with specified shape ratio values) had been calculated with usage of WF2D

method. The obtained results of calculation had been compared to reference values

taken from reference (Murakami [1987]). Considering crack of specified shape is

caused by the fact that analytical solutions in such publications are available only

for few specified cases, which should be considered as their significant limitation.

Required conditions are represented with usage of shape ratios, which combines such

dimensions, as shaft ratio \( r \), width \( 2a \) and depth \( b \) of the crack.

Because of quite good possibility to compare the results directly, model with

geometrical shape ratio of \( b/r = 0.4; b/a = 1.0 \) was selected to further analysis.

Absolute values of above parameters are: \( r = 10 \text{ [mm]} \); \( a = b = 4 \text{ [mm]} \).

According to previous comments considering some remarks of appropriate mod-

elling, shaft cross-section had been modelled with usage of 8 rectilinear segments,

creating regular polygon circumscribing the real circular contour. Also semi-elliptical

shape of crack is approximated by the rectilinear segments, although they are in-

scribed into actual crack shape contour.

Fig. 2. Scheme for determining point location on crack contour using parametric angle \( \phi \).
SIF values in each point of such approximated contour are calculated at the midpoints of each of segments. Their localization are described by the parametric angle $\varphi$ $[^\circ]$. Number of segments approximating crack contour are selected, so that extremal points, where SIF is calculated, correspond to $\varphi_{\text{min}}$ and $\varphi_{\text{max}}$, where are the actual corners of real crack in the element (Fig. 2). For assumed geometry, such situation is the nearest to real conditions, when crack is approximated with 7 segments.

SIF values were calculated for stress distribution corresponding to shaft’s bending, with maximum value $\sigma = 100$ [MPa] at the external contour of the body. Absolute values were then converted into normalized stress intensity factors values ($F_I$), with usage of formula below:

$$F_I = \frac{K_I}{\sigma \cdot \sqrt{\pi} \cdot s}$$

where: $K_I$ - stress intensity factor (SIF), $\sigma$ - maximum stress, $s$ - half of length of arc created by the crack along body surface.

Table 1 and Fig. 3 show results of SIF values calculation for the modelled crack. SIF values $F_I(K_I)$ were evaluated for a few different positions of shaft (which simulates rotation of shaft with determined angle $\theta$).

![Fig. 3. SIF values along crack contour at different rotation angles.](image_url)

Normalized SIF values ($F_I$) had been evaluated for shaft rotation in range between $\theta = 0$ $[^\circ]$ (greatest stress values at the deepest point of crack) to 90 $[^\circ]$ (deepest point of crack in the neutral axis), with angle increment of 30 $[^\circ]$.

As one may notice, character of $F$ values distribution along crack contour corresponds well to the reference value $F_{\text{ref}}$. For $\theta = 0$ degrees distribution is symmetrical in reference to the deepest point, due to symmetry of model referring to stress field,
which takes place for this localization of the crack.

Increasing angle of stress field rotation (which simulates rotation of shaft counter clockwise) results increasing asymmetry of $F$ value distribution, with simultaneous decreasing of values. This is caused by the fact that crack, while rotating, gets closer to the neutral axis. Exclusion may be noticed for the point at left crack corner ($\varnothing = 167.14^\circ$), because this point, as well as other on the left side of shaft axis, in the initial stage of rotation gets respectively closer to the point, where stress values are the highest (which is direct result of character of stress distribution from bending).

Right after exceeding the neutral axis of the body, SIF values become negative. One may also notice that, beside distribution, also values of FI does not differ significantly from reference values - obtained difference between results and reference values at the deepest point of crack does not exceed 4-5%. For $\theta$ equal $90^\circ$ and $\varnothing/\varnothing_{\text{max}} = \sim -1: \sim 1$, difference is about 17%. Nevertheless, this specific position of element section with crack in stress field has less important effect on crack growth analysis results.

### 4 Calculation of SIF for various shapes of cracks in element under rotary bending

This part of the paper describes possibilities to evaluate SIF with usage of point-load weight function, assuming existence of surface fatigue cracks with various shape parameters in circular-shaped element.

Normalized values of the factor ($F_I$) were performed for a few sets of data containing cracks with shape coefficient values as shown in the Table 2.
Table 2. Sets of geometrical parameters of crack and body.

<table>
<thead>
<tr>
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<th>Data set no</th>
</tr>
</thead>
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</tr>
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</tr>
<tr>
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<td>0.1</td>
</tr>
<tr>
<td>$b/a$</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Obtained values of normalized SIF ($F_I$) in the function of parametric angle $\varphi$, for each data set, are shown below. Each series of data on the graphs correspond to the shaft with crack rotated at specific value of $\theta$ angle in the range between 0 and 90 [$^\circ$]. Evaluation of $F_I$ for $\theta = 90 \div 180$ [$^\circ$] had not been done, because of obtaining negative SIF values (crack passes the neutral axis, where tensile stress is replaced by the compressive one), which is not so important, while analysing growth of fatigue cracks. Also analyses for $\theta = -90 \div 0$ [$^\circ$] had been omitted, because in this range stress field is symmetric to the localization of crack, so the results are also supposed to be symmetrical.

Further analyses had been done for cracks with relatively small dimensions comparing to shaft diameter, because of above mentioned difficulties with approximation of real circular cross-section of body contour, when $b/r$ is much higher. If smaller cracks are considered, it is possible to replace real contour with higher number of segments, which may have an effect for the accuracy of results. This allowed to approximate body contour with 32 segments and 15 segments had been used for the crack contour. Although sets #8-#11 had to be done with usage of 8 segments for describing cross-section of the body, in order to allow evaluating SIF for flat cracks.

![Fig. 4. Normalized SIF ($F$) values for crack with ratio: a) $b/r = 0.05; b/a = 0.5$ b) $b/r = 0.1; b/a = 1.0$.](image)
Table 3. SIF \((F)\) values for crack with: a) \(b/r = 0.1; b/a = 0.5\) b) \(b/r = 0.1; b/a = 1.0\) at characteristic points.

<table>
<thead>
<tr>
<th>(\theta[^{\circ}])</th>
<th>a) (174)</th>
<th>a) (90)</th>
<th>a) (6)</th>
<th>b) (174)</th>
<th>b) (90)</th>
<th>b) (6)</th>
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<td>0.5408</td>
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<td>-0.0422</td>
<td>0.0536</td>
<td>0</td>
<td>-0.0536</td>
</tr>
</tbody>
</table>

Fig. 5. Normalized SIF \((F)\) values for crack with ratio: a) \(b/r = 0.15; b/a = 1.5\) b) \(b/r = 0.2; b/a = 2.0\).

Table 4. SIF \((F)\) values for crack with ratio: a) \(b/r = 0.1; b/a = 1.5\) b) \(b/r = 0.1; b/a = 2.0\) at characteristic points.

<table>
<thead>
<tr>
<th>(\theta[^{\circ}])</th>
<th>a) (174)</th>
<th>a) (90)</th>
<th>a) (6)</th>
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<th>b) (6)</th>
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<td>0.0605</td>
<td>0</td>
<td>-0.0605</td>
</tr>
</tbody>
</table>

Data sets #1 - #4 depicted on Fig. 4 and 5, and in Table 3 and 4, are performed for cracks with different depth (starting from semi-elliptical cracks with \(b/r < 1\), through circular cracks, which has \(b/r = 1\), up to cracks with coefficient \(b/r\) value exceeding 1).

Obtained results suggest that for flat cracks (lower \(b/a\) ratio with the same \(a/r\)) character of changes of \(F\) value in the function of \(\varnothing\) angle is significantly different -
for rotation angle $\theta$ nearly 0 [$^\circ$] the highest values of $F$ are noticeable at the deepest point of growing crack, while for circular cracks or deeper, the stress is the most intensive at crack corners. It might be explained by the fact that for flat cracks, changes of stress value in the function of crack depth is quite small. Almost whole crack is under similar stress values, so the function of SIF value along the crack contour is close to the one obtained for crack in uniform tensile stress-field. While crack is deeper (comparing to its width), stress at the far-reaching point of crack is lower, according to the stress in the corners. Hence, in proportion to the stress, SIF value also decreases.

One may notice, that effect of shaft rotation in the fixed stress - field onto the asymmetry of SIF values along crack contour increases for deeper cracks.

For analysed cases difference between $F$ value along crack contour is greater for greater $b/a$ ratio (for the same $b/r$ value). The lower value of the ratio is, the differences between right ($\varnothing = 0$) and left ($\varnothing = 180$) corner are lower, if $\theta$ is unequal 0. Another group of analysed sets had been done for the same crack dimensions and shape ($b/a = 1.0$), but for various sizes of the body cross-section. Obtained results for data sets #5 - #7 are depicted at Fig. 6 and Table 5.

As one may notice, for circular cracks that had been analysed, which $b/r$ ratio is less than 0.1, influence of changing this ratio onto obtained SIF values is rather insignificant. If rotation angle $\theta = 0$, either character of the function or SIF values at particular points of crack contour are quite similar, although for cracks with smaller dimensions (comparing to body size) $F_I$ values are slightly higher.

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**Fig. 6.** Normalized SIF (F) values for crack with ratio: a) $b/r = 0.01$; $b/a = 1.0$ b) $b/r = 0.02$; $b/a = 1.0$ c) $b/r = 0.05$; $b/a = 1.0$. 
Table 5. SIF \( (F) \) values for crack with ratio: a) \( b/r = 0.01; b/a = 1.0 \) b) \( b/r = 0.02; b/a = 1.0 \) c) \( b/r = 0.05; b/a = 1.0 \) at characteristic points.

<table>
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<tr>
<th>( \theta ) [deg]</th>
<th>( \theta )</th>
<th>( \theta )</th>
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</table>

It is caused by fact, that variability of stress field along the contour is lower, and smaller cracks are nearer to the location of maximum stress values (on shaft’s external contour).

In case of \( \theta > 0 \) character of the SIF values variability along crack contour is also very similar, comparing to each other, independently from value of \( b/r \) ratio.

The last group of data, containing sets \#8-\#11 with constant depth of crack (constant \( b/r \)) assumed variability of crack shape in range \( b/a \) from 0.25 to 2.0. Because of difficulties to contain so flat crack on the basis of previously generated polygon, in this case approximation of the body had been assumed to be done with usage of regular octagon. Fig. 7 and Table 6 show values of normalized SIF along the crack contour.

Fig. 7. Normalized SIF \( (F) \) values for crack with ratio: a) \( b/r = 0.1; b/a = 2.0 \) b) \( b/r = 0.1; b/a = 1.0 \) c) \( b/r = 0.1; b/a = 0.5 \) d) \( b/r = 0.1; b/a = 0.25 \).
Table 6. SIF (F) values for crack with ratio: a) b/r=0.1; b/a=2.0 b) b/r=0.1; b/a=1.0 c) b/r = 0.1; b/a = 0.5 d) b/r = 0.1; b/a = 0.25 at characteristic points.

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<td></td>
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</table>

Results of analysis for this series of data show that the character of obtained functions significantly differs for flat cracks. Asymmetry of SIF values for left and right half of the crack is considerably greater for flat cracks in comparison to cracks with smaller width, which is especially noticeable for the crack with b/a = 0.25. As it reveals, stress level in crack corner opposite to rotation directory may be higher after shaft’s rotation than while deepest point is in maximum stress point. It is caused by the fact that for flat and wide cracks, points on its contour near to corner, for θ = 0 [°] might be located in the lower stress zone, comparing to the situation after shaft’s rotation.

Performed analyses reveals that it is possible to apply point-load function method to calculate SIF values at the front of fatigue cracks, propagating in elements undergoing rotary bending.

5 Crack growth analysis perspective

Hence, this means also applicability of the presented method for analyzing crack growth, which enables to assess fatigue resource of elements under considered state of loading. Nevertheless, in particular cases, some difficulties might occur, while using the above mentioned numerical procedure for analyzing cracks of great width. As mentioned before, these kind of difficulties concerns to necessity of locating crack’s corners on the horizontal line, coinciding with the beginning of coordinate system. This situation may occur either for big cracks (Fig. 8a), which initial dimensions does not allow to locate them in specific way in circular cross-section (high b/a and b/r values), or for cracks with relatively small dimensions (Fig. 8b). The last ones may be possible to locate at the approximated polygon’s basis at first stage of growth,
without losing too much of results accuracy, but as they increase their dimensions due to fatigue, they may not fulfill the criterion on the further stage of growth. It implies necessity to discontinue calculations without reaching end, or, if possible, continue with decreased accuracy of actual cross-section contour approximation or after modifying it, as depicted on Fig. 8b. Helpful may be the fact, that obtained results are quite similar, independently from numbers of segments approximating body contour, which may be noticed by comparing graphs on Fig. 4b and 7b ($b/a = 1.0$ and $b/r = 0.1$) - the same contour is approximated with usage of polygon with, respectively, 32 and 8 segments.

Fig. 8. Idea of body contour modification during analyzes of crack growth: a) for cracks with significant initial dimensions; b) for crack, witch size increases during calculations.

In order to take full advantage of WF2D method, without loosing results accuracy and with appropriate conformity of model according to actual situation in element’s cross-section with propagating crack, functionality of numerical procedures using point-load weight function should be improved to add possibility of computing while contour of crack’s free surface is approximated with convex, simple polygonal chain.
(Fig. 9), permanent through the whole stage of analyzed crack growth. Such improvement is possible, according to general features of the method, but it requires further development.

6 Conclusions

Method of two-dimensional weight function gives good results of SIFs and can be used for calculation of stress intensity factor in the machine elements of circular cross section undergoing rotary bending stress.

SIF results reasonably agree with reference values for stress fields corresponding to rotary bending. For most of considered cases the difference is less than 5%.

It is possible to apply WF2D method to analyze crack growth at considered type of loading, even for quite high value of crack’s size to element’s size ratio, with insignificant lost of results accuracy.

Representing real cross-section contour of the element more precisely, which provides to get maximal (achievable for WF2D method) accuracy of SIF evaluation, requires further development of computation procedures.

References


Reinhardt, W. and Glinka, G. (1997). Program WF2D (vol.1.0) for calculation of SIF with the two-dimensional weighting function method. SAFED.