CONTENTS AUTHORS

15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

TEMPERATURE CHANGES ON THE SLIDING SURFACE OF THE BRAKING DRUM ON A CRANE WITH TWO SHOES

Mirsad Colic, Adil Muminovic
Faculty of Mechanical Engineering
Vilsonovo setaliste 9, Sarajevo
B&H

ABSTRACT
It is known that the operation of the brake is characterized by the conversion of mechanical energy into heat which results in an increase of temperature on contact's surface of sliding parts. Increased temperature affects the reliability of the brake and reduces the brake lining's life time. It is therefore very important to the design or selection of the brake to know the heating level for the assumed operating conditions. This paper presents an example for checking the temperature of the cranes brake. The set up mathematical model was solved numerically (finite volume method). The used method was tested on examples that have an analytical solution and it can be used for an arbitrarily long period of cranes work.
Keywords: Brakes, Braking drum, Friction, Temperature,

1. INTRODUCTION
Brakes have the task to enable movement control of the mechanism on which they are built on. While doing this all the conditions in which the mechanism works must be satisfied. The brakes are exposed to different working conditions during the exploitation. When talking about crane brakes, then the conditions are dependent on the purpose of the brake and the mechanism the brake is built on. When designing the crane mechanism the brakes are usually picked from existing ones. This is relied on experienced solutions that proved acceptable. This way the difficulties related to heat transfer are avoided (heating of brake parts). It is known that the work of the brake is characterized by the conversion of mechanical energy into heat. This results as warming-up and temperature increment of brake parts. It is also known that the temperature on the contact surfaces of the lining and the drum has its maximal value at some point during the breaking. The high temperatures are affecting on the life time of the frictional linings and the reliability of the brake. Using the shown method the temperatures on the sliding surface of the regulatory brake drum can be predicted. The computer program allows the brake's work simulation for an arbitrarily long period of brake's work.

2. MATHEMATICAL MODEL AND THE NUMERICAL PROCEDURE
When solving a heat transfer problem inside a body using the finite volume method it is started from the energy equation written in the integral form [2]:

$$\frac{\partial}{\partial t}\int_V \rho c T dV = \int_S \lambda_d \frac{\partial T}{\partial x_j} n_j dS + \int_V q_i dV \qquad \text{... (1)}$$

Where: ρ-density, c-specific heat, T-temperature, t-time, x_j-coordinates, λ_d-coefficient of heat flow, q_i -specific amount of heat which for a unit time appears or disappears, V -volume of a cell, S -total wrapping area, n_j-unit vector perpendicular to the outside area S.

2.1. Starting ad lining values

The assumption is that the starting temperature is uniform, so that the following can be written:

$$T(x_{j,0}) = T_p = const \quad \text{... (2)}$$

Limiting values are defined by the interchange of temperature between the surface of a body and the surrounding environment so the limiting heat flux is:

$$q_B = -\lambda_d \left(\frac{\partial T}{\partial n}\right)_B = q_{zr} + q_{konv} \quad \text{... (3)}$$

Where: $(\partial T/\partial n)_B$- temperature gradient on the bordering body, q_{zr} i q_{konv} - heat taken from free body surfaces by radiation and convection.

2.2. Numerical Procedure

Equation (1) with the starting and limiting values described above (2) and (3) can be solved by methods of final volumes (MKV) [2] where process time has to discretize the given number of time intervals δt, space domain to the N checking volumes (KV). Integrating the equation to the controlling interval volume (KV) using linear space change variable and implicit time differentiation we are able to derive equation (1) algebraically:

$$a_P T_P = \sum_K a_K T_K + b, \qquad (K = E, W, N, S, T, B) \quad \text{... (4)}$$

Which is equated iteratively [2].

3. NUMERICAL EXAMPLE

Before calculating the temperature on the breaking drum the solving method is tested on examples that have known solutions. The first example (Figure 1) is related to warming up the plate that is inserted into an oven preheated to 800 ^{o}C [1]. The results show a temperature change in the middle (in) and on the surface of the plate (out). A good matching of the calculated results with the earlier known results can be seen from the following figure.

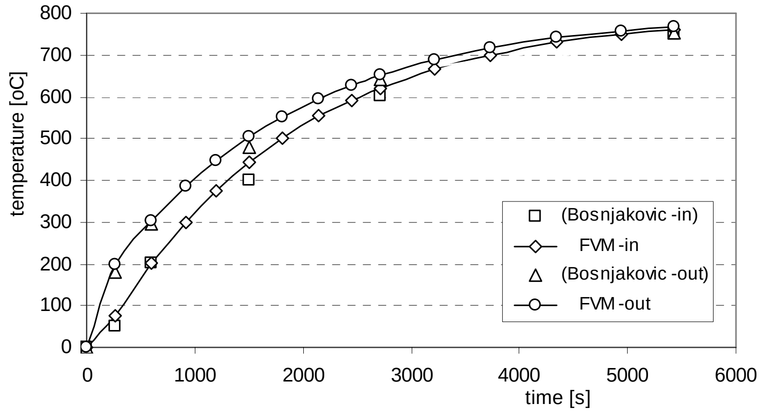


Figure 1. Temperature change in the mddle of the plate

The second example is related to the cooling of the disk with diameter of 200mm and height of 120mm [5]. The disk was heated up to the temperature of 300 ^{o}C earlier and inserted into a mixture of ice and water what is causing the temperature on the surface to drop instantly to 0 ^{o}C. The calculated results of the temperature change in the middle of the disk are shown on Figure 2. A good matching of the calculated results with the results known from literature can be seen from the figure. On Figure 3 are shown calculated temperature results on the disk's intersection after 120 s of cooling.

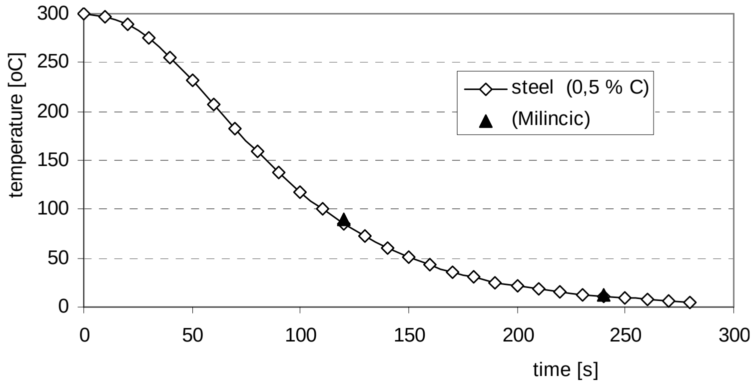
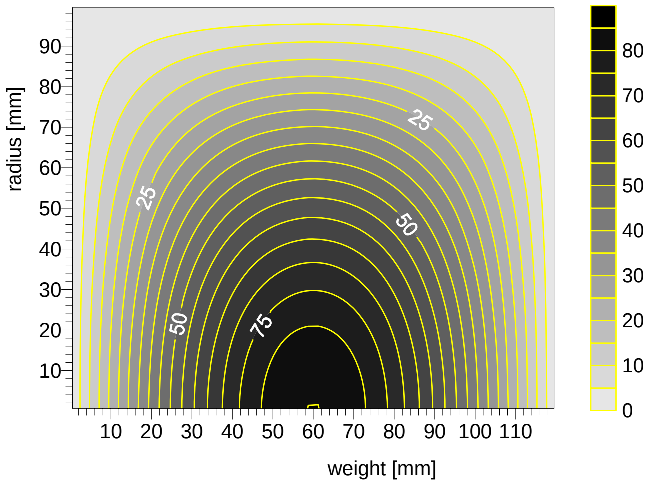


Figure 2. Temperature change in he middle of the disk



Figue 3. Temperature layout o the intersection of the disk

3.1. Breaking modeling and calculated results

Mechanical energy is transformed to heat on the breaks which is then transferred on the brake. As an example for calculating the temperature a brake's work while lowering the load is simulated. During the brake's work the velocity of the breaking drum does not change. This means that the heat that is transferred to the brake per unit time, expressed per unit area (heating flux) is defined as:

$$q = q_b + q_p \cong q_b = \frac{\eta\ m_T\ g\ v_s}{2\ A_p} = \mu\ p_{sr}\ v \qquad \dots (5)$$

Where: q_b -heat transferred to the drum, q_p -heat transferred to shoes, A_p -contact surface amog drum and one shoe, m_T -cargo mass, v_s -speed of lowering cargo, μ -frictional coefficient, p_{sr} -average pressure value on contactsurface among drum and shoe and v -skating speed.

For the calculation a brake with breaking drum's diameter of 200mm which is made of steel with the label EN:X27CrMoV51 is selected. The number of drum's rotations is 500 1/min while the temperature of the environment is 20 ^{o}C.

The obtained calculation results describe the temperature change on the sliding surface of the drum. The temperature change is tracked in two points on the surface of the drum on 20mm distance from the sliding surface edges. The temperature change after the breaking and on the end of every breaking cycle in these points is shown on Figure 5. Curves 1 show temperature changes on the 20mm point and the curves 2 on the 75mm point.

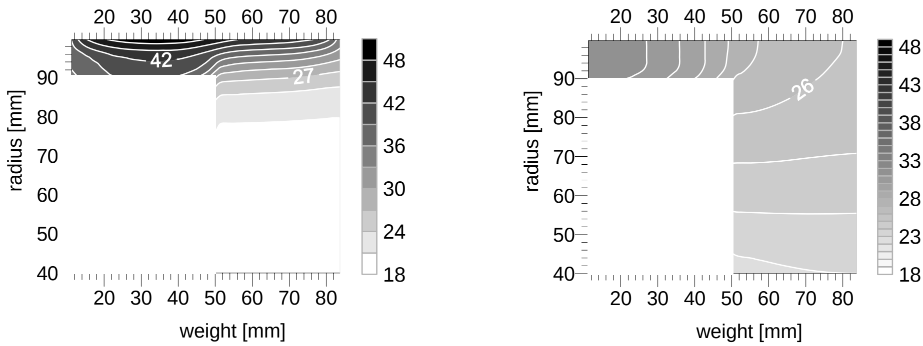


Figure 4. Temperature distribution, from insaide drum, after lowering cargo 10 s (left) and on the end of cycle 160 s (right).

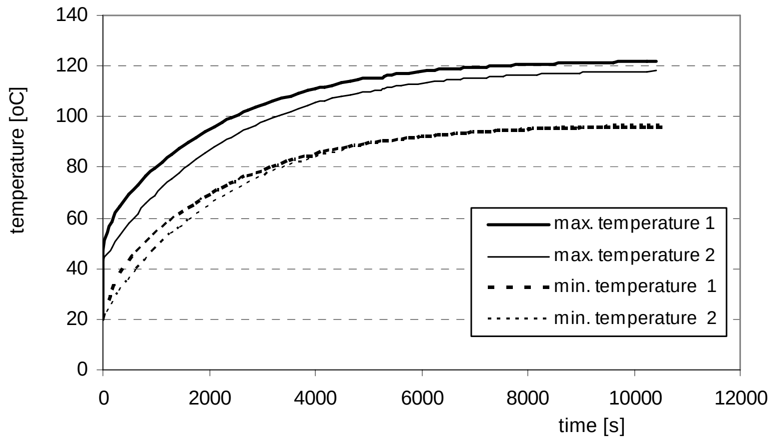


Figure 5. Temperature change, at points 20 mm and 75 mm, during 3 hours of crane work.

4. CONCLUSION

The shown example demonstrates that the temperature to which the brake will be heated up during the work can be known during the design phase or while selecting the brake. It can be seen that the temperature change can be followed during a long period of time if needed. This all can positively affect on the brake's life time and on the reliability. Working conditions of the crane (brake) must be known in order to be able to do the calculation.

5. REFERENCES

[1] Bosnjakovic F.: Nauka o toplini II, Tehnicka knjiga, Zagreb, 1976.,

[2] Demirdzic I., Ivankovic A.: Finite Volume Stres Analysis, Imperial Colege of Science, Technology and Medicine University of London, 196/97.,

[3] Dimitrijevic D, Savic Lj.: Racunarsko programiranje, Naucna knjiga, Beograd, 1986.,

[4] Ernst H.: Die Hebezeuge, Band I, Braunschweig, 1966.,

[5] Milincic D. B.: Prostiranje toplote, Univerzitet u Beogradu, Masinski fakulet, Beograd, 1979.