Theoretical and experimental investigations of coolant flow in inlet channels of the BTA and ejector drills

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The coolant flow through inlet annular channels in BTA and ejector drills is investigated. The study was conducted in order to understand the influence of the channel's parameters (the channel's clearance variation along its length and eccentricity) on the coolant pressure distribution and hydraulic resistance. A new design of the ejector drill with the eccentrical location on the inner tube is proposed.

A study is made of the stability in the coolant flow in the inlet annular channels. The appearance of instability is explained by the presence of Taylor macrovortices in these channels under certain combinations of boring bar rotating velocity and axial flow velocity. In order to define the unstable regimes (the critical Reynolds numbers), the mathematical model for non-isothermal flow through the annular channel is solved. The heat transfer from the swarf to the incoming coolant is investigated under different flow conditions.

Key words: coolant flow, BTA and ejector drills, macrovortices, annular channels

NOTATION

A_h	total cross-sectional area of the outlet holes of the drill head
c_p	specific heat of the coolant at constant pressure
C_1, C_2	constants
d_b	diameter of the inner tube
d_{b1}, d_{b2}	diameters of the inner tube in Fig. 7
d_{e1}, d_{e2}	equivalent diameters of annular channels restricted by diameters D_b and d_{b1}, D_b and d_{b2}, respectively
D	drill diameter (Fig. 7)
D_b	internal diameter of the boring bar
f_{ag}	friction factor for the annular channel
f_{ag1}	friction factor for the annular channel restricted by diameters D_b and d_{b1}
f_{ag2}	friction factor for the annular channel restricted by diameters D_b and d_{b2}
f_R	friction factor for the annular channel with rotating wall
g	gravitational constant and specific gravity of the coolant
Gr	Grasthov number
H_{AB}, H_{BC}, H_{CD}	hydraulic heads at parts AB, BC and CD respectively
$H_\Sigma, H_{\Sigma BCD}$	total hydraulic heads at the inlet [equation (44)] and at point B [equation (43)]
l_e	length of the annular channel from the inlet point to point B (Fig. 7)
l_l	distance between the connector and the outlet holes of the drill head
l_o	length of the annular channel between point B and point C (Fig. 7)
L	length of the annular channel
Nu	Nusselt number
p	current coolant pressure
P_Σ	inlet coolant pressure
Pr	Prandtl number
p, Θ, ρ	pressure, temperature and density of perturbations [equation (29)]
p_{in0}	inlet coolant pressure
p_1	outlet coolant pressure
Δp	pressure difference between inlet and outlet
Q	current flowrate
Q_c	total flowrate in the case of concentric and stationary walls
Q_l	total flowrate in the case of eccentric walls
Q_{opt}	optimal coolant flowrate
Q_u	flowrate per unit width of the flow
Q_W	flowrate through the ejector nozzle
Q_Σ	necessary total flowrate
$Q_{\Sigma BCD}$	total flowrate for parts BC and CD (Fig. 7)
r	current radius
r, ϕ, z	non-dimensional cylindrical coordinates
R_1	radius of the inner wall of the annular channel
R_2	radius of the outer wall of the annular channel
Re	Reynolds number
Re_e	effective Reynolds number
Re_{cr}	critical Reynolds number
S_{AB}, S_{BC}, S_{BD}	hydraulic resistance coefficient for parts AB, BC and CD respectively (Fig. 7)
Ta	Taylor number
u, v, w	coordinate system [equation (30)]
V_b	velocity of the boring bar
V_l	effective coolant velocity
V_z	axial coolant velocity
V_0, p_0, ρ_0	current velocity, pressure and density of the coolant along the cross-section

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