Vasile Mihaela Alina
1311EC

Electrical Contacts

I Work topics

1. Verification of steady-state heating of current path contacts in TCA-200 contactor (nominal current: 200 A) using the Wiedemann-Franz-Lorentz relation.

2. Plotting the characteristic curve of contact resistance as a function of pressing force $R_c = f(F)$ for the 2 main contacts.

II Electrical assembly diagram

Components: C - cale de curent a contactorului TCA-200
T - transformator de curent intens
AT - autotransformator reglabil
Sh - șunt de curent intens (1000A; 150 mV)
mV_1 - aparat digital fol. ca milivoltmetru de c.a.
mV_2 - milivoltmetru de c.c.
T_{c1}, T_{c2} - termocuple.

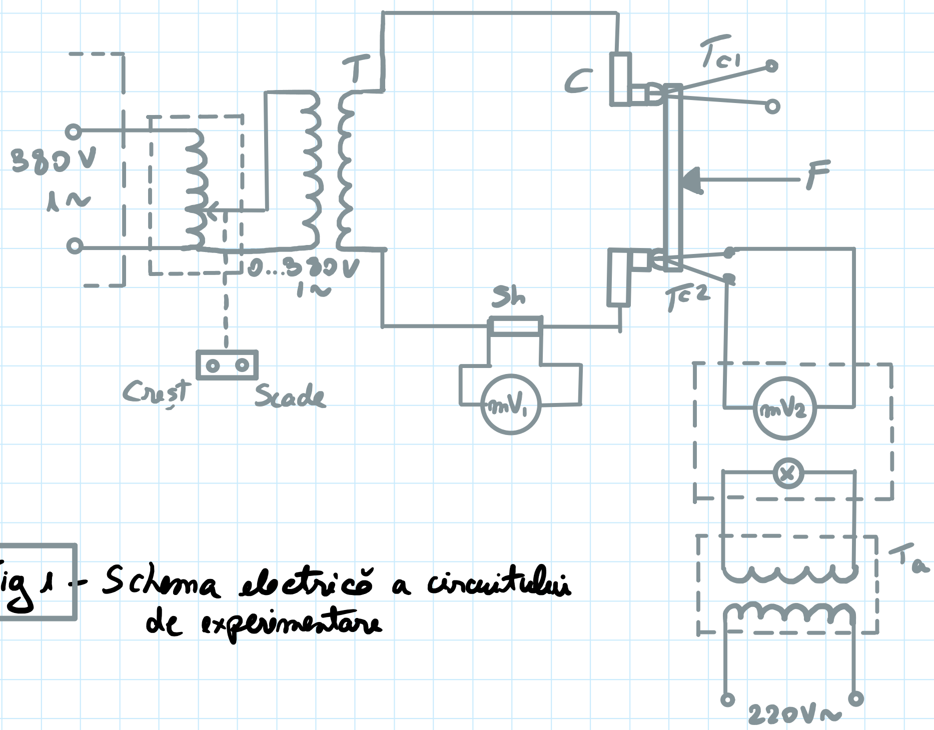
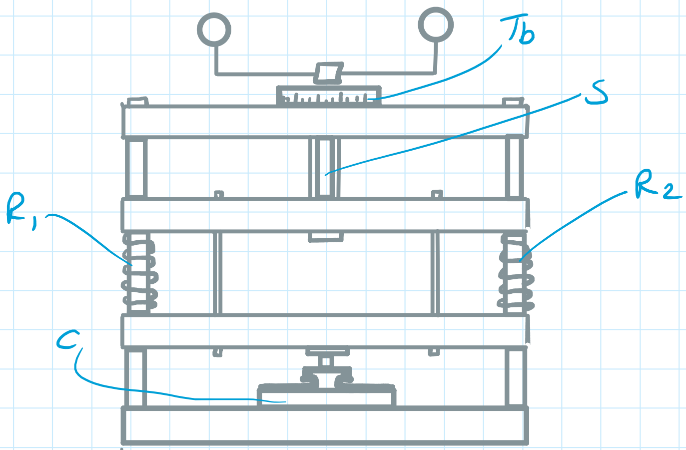


Fig 1 - Schema electrică a circuitului de experimentare



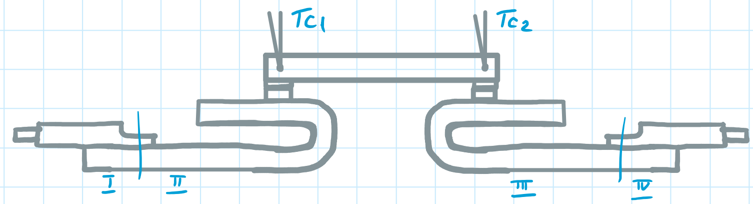


Fig 2 - Schița dispozitivului de realizare a forței de presiune în contact

Fig 3 - Schița sistemului de contacte ale unui contactor

Procedure:
→ Setup: – Assemble the circuit as shown in Fig 1
– use force application device (Fig2) to adjust the contact pressing force (F) between 0 & 100 N by rotating the graduated drum Tb (1 rotation = 1 N force)
→ Contact force adjustment: – detect the contact position using the digital milivoltmeter (mV2) & adjust the pressing force
→ Current application: – establish & maintain a ct current of $i = 200\,A$ in the circuit
→ Heating study: – measure contact heating for pressing forces: F = 100, 75, 50, 25 N in sequence.
– wait 30 min for steady-state heating & monitor using thermocouples Tc1 & Tc2.
→ Data collection – record the contact resistance $R_c = f(F)$ & compare heating measured by thermocouples with calculations using the formulas
→ Precautions: – maintain ct current during experiment
– avoid opening contacts under load / altering positions to prevent damaging
– adjust force only after interrupting the load.

Formulas:

$$\theta = \theta_{max} + \sum_{i=1}^{n_c} \theta_{ci}$$

θ_{max} = încălzirea căii de curent prin efect Joule datorită curentului i
n_c = nr de contacte aflate în apropiere
θ_{ci} = încălzirea proprie a contactului i

$$\theta_{max} = \frac{\theta_{0max}}{1 - \alpha_R \cdot \theta_{0max}}$$

$$\theta_{0max} = \frac{\rho_{20}\, J^2 A}{\alpha \cdot l_p}$$

$\rho_{20} = 1{,}75 \cdot 10^{-8}\ \Omega m$

$\alpha = 16\ W/m^2\,°C$

$\alpha_R = \frac{1}{273}\ \frac{1}{°C}$

$$\theta_{omax} = \frac{\ldots}{\alpha \cdot l_p}$$

$\alpha = 16\, W/m^2\,°C$

$\alpha_R = \frac{1}{273}\ \frac{1}{°C}$

$x = 20\,mm \qquad Y = 2{,}5\,mm$

$$l_p = 2(x+Y)$$

$$A = x \cdot Y$$

$$J = \frac{i}{A}$$

$$L\left(T_\theta^2 - T_0^2\right) = \frac{U^2}{4}$$

$$T_{\theta i} = \sqrt{\frac{U_{ci}^2}{4L} + T_0^2}$$

L = cifra lui Lorentz $= 2{,}4 \cdot 10^{-8} (V/°K)^2$

T = temp. contactului în grade absolute

T_0 = temp. căii de curent în °K la distanță mare de pctul de contact

U_c = căderea de tensiune [V] în contact, măsurată cu aparatul digital

$\theta_{ma} = 23°C$

$$T_0 = 273{,}15 + \theta_{omax} + \theta_{ma}$$

$$\theta_{ci} = T_{\theta i} - T_0$$

III Table of measured & calculated values

F [N]	contact	încălzire U [mV]	măsurat θ [C]	U_{ci} [mV]	θ_{ci} [C]	$\sum \theta_{ci}$ [C]	θ calc [C]	R_c calc [μΩ]
100	sus (1)	0,6	10	8,6	1,19	2,38	23,31	43
	jos (2)	0,9	21	8,6	1,19			43
75	(1)	0,8	20	10,3	1,45	2,86	23,79	51,5
	(2)	1,3	29	9,9	1,41			49,5
50	(1)	0,9	21	11,9	2,1	3,51	24,44	59,5
	(2)	1,4	32	9,9	1,41			49,5
25	(1)	1	22	13,5	2,85	5,62	26,55	67,5
	(2)	1,6	34	12,8	2,77			64
10	(1)	1,2	25	17,4	4,19	8,9	29,83	87
	(2)	1,7	39	17	4,71			85

IV Calculation example

for $U_{ci} = 9{,}9\ mV$, $R_c = \frac{U_{ci}}{i}$, $i = 200\ A$ $\Rightarrow R_c = \frac{9{,}9 \cdot 10^{-3}}{200} = 4{,}95 \cdot 10^{-5}\ \Omega = 49{,}5\ \mu\Omega$

for $U = 1\ mV \Rightarrow \Theta = 45^\circ C$ (tensiunea electromotoare la termocuplele Cupru-Constantan cu sudură la rece)

$\theta_{ma} = 23^\circ C$

$\theta = \Theta - \theta_{ma}$ $\Rightarrow \theta = 45 - 23 = 22^\circ C$

$\rho_{20} = 1{,}75 \cdot 10^{-8}\ \Omega m$

$J = \frac{i}{A}$

$i = 200 A$

$A = x \cdot y$

$x = 20 mm$

$y = 2{,}5 mm$

$\Rightarrow A = 20 \cdot 2{,}5 = 50\ mm^2 = \boxed{A = 50 \cdot 10^{-6} m}$

$\Rightarrow J = \frac{200}{50 \cdot 10^{-6}} = \frac{200}{0{,}00005} = 4 \cdot 10^6\ A/m^2$

$\boxed{J = 4 \cdot 10^6\ A/m^2} = 4\ MA/m^2$

$\alpha = 16\ W/m^2\,{}^\circ C$

$l_p = 2 \cdot (x+y) = 2(20+2{,}5) = 45\ mm = \boxed{45 \cdot 10^{-3} m = l_p}$

$$\theta_{0max} = \frac{\rho_{20} \cdot J^2 \cdot A}{\alpha \cdot l_p} = \frac{1{,}75 \cdot 10^{-8} \cdot (4 \cdot 10^6)^2 \cdot 50 \cdot 10^{-6}}{16 \cdot 45 \cdot 10^{-3}} = \frac{1400 \cdot 10^{-2}}{720 \cdot 10^{-3}} \simeq 19{,}44\ C$$

$\boxed{\theta_{0max} = 19{,}44\ C}$

$\alpha_R = \frac{1}{273}\ \frac{1}{^\circ C}$

$$\Rightarrow \theta_{max} = \frac{\theta_{0max}}{1 - \alpha_R \cdot \theta_{0max}} = \frac{19{,}44}{1 - \frac{1}{273} \cdot 19{,}44} = \boxed{20{,}93\ C = \theta_{max}}$$

$$T_0 = 273{,}15 + \theta_{max} + \theta_{ma} = 273{,}15 + 20{,}93 + 23 = \boxed{317{,}08\ ^\circ K = T_0}$$

for $U_{ci} = 17 mV$

$L = 2{,}4 \cdot 10^{-8}\ (V/^\circ K)^2$

$T_0 = 317{,}08\ ^\circ K$

$$\Rightarrow T_{\theta i} = \sqrt{\frac{(17 \cdot 10^{-3})^2}{4 \cdot 2{,}4 \cdot 10^{-8}} + (317{,}08)^2} = \sqrt{\frac{289 \cdot 10^{-6}}{9{,}6 \cdot 10^{-8}} + 100539{,}7264}$$

$\boxed{T_{\theta i} \simeq 321{,}79\ K}$

$\Rightarrow \theta_{ci} = T_{\theta i} - T_0 = 321{,}79 - 317{,}08 = 4{,}71\ C$

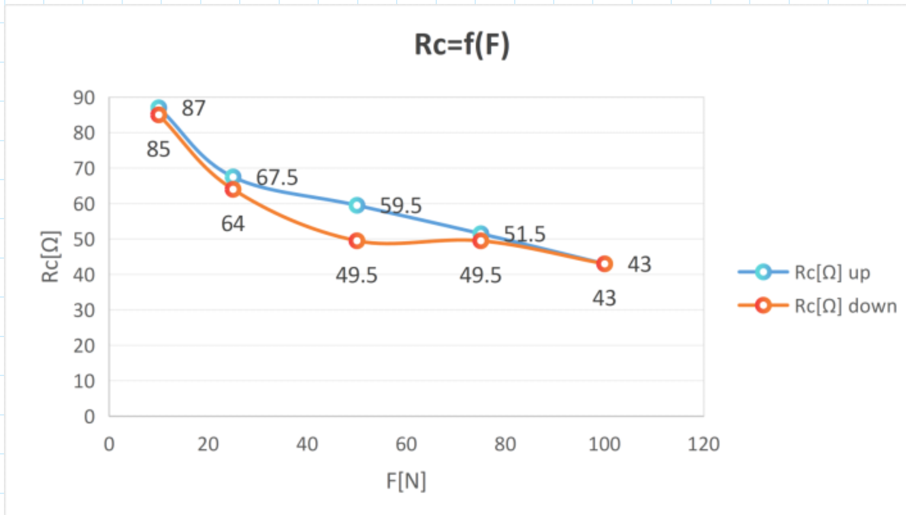
for $\theta_{ci}(1) = 1{,}19\ C$ | $\Rightarrow \Sigma\theta_{ci} = 2 \cdot 1{,}19 = 2{,}38\ C$ | $\Rightarrow \theta = 2{,}38 + 20{,}93 = 23{,}31\ C$

$\theta_{ci}(2) = 1{,}19\ C$

$$\theta = \Sigma\,\theta_{ci} + \theta_{max}$$

V Graphs

F[N]	Rc[Ω] up	Rc[Ω] down
100	43	43
75	51.5	49.5
50	59.5	49.5
25	67.5	64
10	87	85



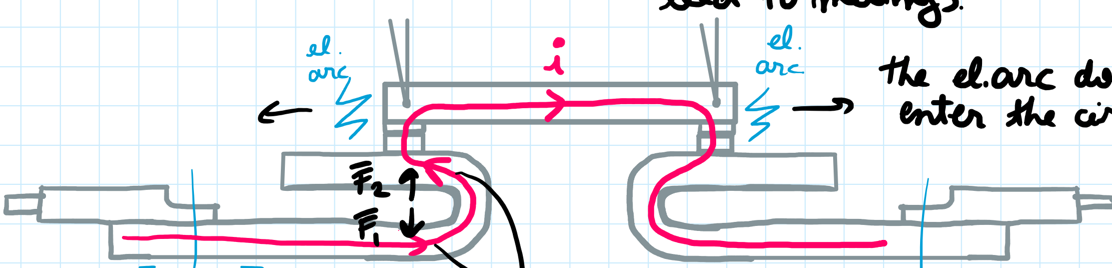
VI Observations & Conclusions

the electric arc $\Rightarrow \begin{cases} \text{wear} \\ \text{maximum overtemp (tranzitorie)} \end{cases}$

pressure force = big $\Rightarrow$ tasare
(system = oversized)

the contacts $\neq$ perfectly flat (with a light radius) $\Rightarrow$ the electric arc is pushed towards the arc extinguishing chamber.

geometry of the current's way $\Rightarrow$ loop effect $\rightarrow$ we force the el. arc to enter & not towards the circuit (which would lead to melting).



the el.arc doesn't enter the circuit

A (source)

B

different directions of the current $\Rightarrow$ repealing force

↗ (sources)   different directions of the current => repealing force between the bars   B

↗ Force applied => ↘ R_c (at 10N -> almost half of the resistance for 100N)
=> better conducting the current

↘ Force applied => ↗ R_c (contact resistance)
=> ↗ heat (more damages) + energy loss
=> ↘ lifespan of contacts

VII Q & A

1 What is meant by contact resistance?

the el. resistance found at the interface of 2 el. contacts.
depends on surface roughness, contact pressure, oxidation, the overall state of the contacts.

2 What materials are used to construct switching device contacts?

materials with high conductivity & resistance to wear & oxidation
ex: Ag, Cu, alloys

3 What are the theoretical & practical models of contacts?

theoretical => microscopic contact spots, no damage to them, everything is perfect
practical => mechanical + electrical analyses of real-life contact systems under operational conditions

4 What is the disturbance film & how does it influence contact resistance?

Def: thin layer of oxide, dirt or contaminants on the contact surface.

It ↗ the contact resistance by ↘ the effective conductive area.

5 What factors influence the contact resistance?

material of the contact -> roughness of the surface, state of material (oxidation, corrosion)
cleanliness of surface
force (contact pressure)
Temperature

6 How is the contact resistance influenced by applied force? What is fritting (mechanical & electrical)?

↗ Force => ↘ contact resistance (the contact area = larger + surface films are

↗ Force => ↘ contact resistance (the contact area = larger + surface films are broken through)

Fritting = local melting at contact spots due to electrical / mechanical stress => alter the contact surface.

⑦ What equations can be used to det. the contact heating & under what conditions?

$$\Theta_{max} = \frac{\rho_{20} \cdot J^2 \cdot A \cdot \ell_p}{K}$$

Wiedemann - Franz - Lorenz relationship: $\Theta_{c_i} = \sqrt{\frac{(U_{ci})^2}{4L} + T_0^2} - T_0$

} steady-state current conditions

⑧ What functional types of contacts do you know?

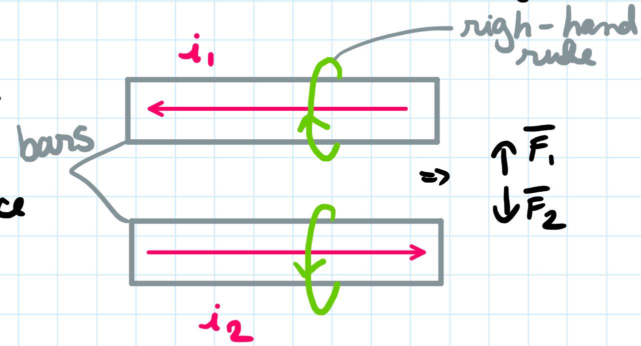
- fixed
- movable : relays, switches
- sliding : trolley busses, trams, trains

⑨ How does contact wear influence their heating?

contact wear => ↗ surface roughness => oxide films | => elevate contact resistance => ↗ heating

⑩ Explain the repulsion force in contacts.

current => magnetic field
current + opposite direction => repulsion force
+ same direction => attraction force



⑪ What is the relationship between contact voltage & heating?

$P = U_c \cdot i$ ~ contact heating = proportional to the square of the voltage drop across the contact

$$\nearrow U_c \xRightarrow{\text{ressistive losses}} \nearrow \text{heating}$$