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INFLUENCE OF SLENDERNESS RATIOS OF A MULTI-HOLE CERAMIC FILTERS AT THE EFFECTIVENESS OF PROCESS OF FILTRATION OF NON-METALLIC INCLUSIONS FROM LIQUID STEEL

WPŁYW SMUKŁOŚCI WIELOOTWOROWEGO FILTRA CERAMICZNEGO NA EFEKTYWNOŚĆ PROCESU FILTRACJI CIEKŁEJ STALI Z STAŁYCH WTRĄCEŃ NIEMETALICZNYCH

The paper presents the results of investigations of the process of filtration of solid non-metallic inclusions from liquid steel with use of multi-hole ceramic filters (filtrating surfaces) characterised by a varying slenderness ratios. In order to eliminate the negative influence of the ambient air atmosphere the investigations have been carried out under a protective argon atmosphere. The experimental results obtained have proved earlier suggestions of papers [9-12] about the negative influence of ambient air atmosphere, as well as the essential influence of slenderness ratio of the used multi-hole ceramic filter at the increase of effectiveness of the liquid steel refining processes carried out through steel filtration.

Keywords: steel, refining, ceramic filter, solid non-metallic inclusions, filter slenderness ratios

W pracy przedstawiono wyniki badań procesu rafinacji ciekłej stali z stałych wtrąceń niemetalicznych przy pomocy wielootworowych filtrów ceramicznych charakteryzujących się zmienną smukłością (powierzchnią filtracyjną). W celu wyeliminowania negatywnego wpływu otaczającej atmosfery powietrza badania przeprowadzono w atmosferze ochronnej argonu. Otrzymane wyniki eksperymentów potwierdziły wcześniejsze sugestie autorów prac [9-11, 15] o negatywnym wpływie otaczającej atmosfery powietrza jak również istotnym wpływie smukłości stosowanych wielootworowych filtrów na wzrost skuteczność rafinacji ciekłej stali poprzez jej filtrację.

1. Introduction

In response to the growing requirements of steel product consumers, especially in relation to the steel metallurgical purity, the newer and newer methods of the liquid steel refining are researched to remove the non-metallic inclusions and damaging impurities and, at the same time, enhance the quality of finished steel products. Focusing the present-day research of steel making processes on the terminal process stages is motivated by the need to achieve at reasonable costs the high quality, high performance steel products. The research works being carried out in this area are primarily concerned with:

- processes of liquid steel refining to prepare the material for the continuous steel casting,
- research of the steel flow hydro-dynamics and steel mixing within the system of main ladle – intermittent ladle –CC machine's crystallizer.

It can be concluded from the hitherto existing experience [1, 2] that the traditional post-furnace steel processing (especially of steel deoxidized with use of a depositing method, e.g. by means of aluminium) does not guarantee high metallurgical purity of the steel. Additionally the presence of non-metallic inclusions in steel, namely Al_2O_3 oxides, disturbs the continuous casting process due to the phenomenon of covering the ladle discharge nozzles by a layer of such inclusions. According to opinions of many research centres [3-6] the filtration of liquid steel by means of multi-hole ceramic filters can be the effective and economical method of removing the non-metallic inclusions from liquid steel. The results of the laboratory and field research works carried out hitherto give the evidence of essential decrease in contents of non-metallic inclusions and damaging impurities in the filtrated steel [7-16]. However the effectiveness of this method of steel refining varies greatly depending on local refining conditions. The reason for these variations is probably in a phenomenon of secondary oxidation of

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filtrated steel by oxygen contained in the air [4, 5, 7]. In connexion with the above mentioned a definition of ***a multi-hole ceramic filter slenderness ratio*** has been proposed to be introduced to the research practice, which is calculated as a ratio between length and width of the filtrating channel (λ = h/d). Using this coefficient we obtain the possibility to compare the filtration effectiveness of different types of ceramic filters, not only for filters with cylindrical filtrating orifices, but also for other types, e.g. with orifices of rectangular section. The aim of the developed and performed laboratory research works has been to verify the influence of slenderness ratios of multi-hole ceramic filters (filtrating surfaces) at the effectiveness of filtration of solid non-metallic inclusions from liquid steel.

2. Results of the laboratory research of steel filtration

The laboratory research works have been carried out in the laboratory of Metallurgy Department of the Silesian Technical University. Five steel melts, 11 kilogram in weight (five melts for S1 filter slenderness ratio (λ_1 = 1.47) and five ones for S2 filter slenderness ratio (λ_2 = 4.44), have been heated to temperature of about 1853 K, deoxidized subsequently with use of the singular deoxidizing agent in form of metallic aluminium, then poured into the mould with a special pouring system (Fig. 1) provided with an integrated ceramic filter in the ambient argon atmosphere. The argon protective atmosphere has been generated in a special caisson (Fig. 2), where the mould, "receiving" the filtrated steel, has been placed together with the whole filtration system. The multi-hole ceramic filter used for steel filtration (Fig. 3), manufactured by the company of Keramtech s.r.o. Žacleř (Czech Republic), has been made on the base of mullite ($3Al_2O_3{\cdot}2SiO_2$). The filters used have had equal orifice numbers (19), diameters of $8{,}1{\cdot}10^{-6}$ m and the total filtrating surface of $5802{\cdot}10^{-6}$ m^2 for S1 filter slenderness ratio and $17406{\cdot}10^{-6}$ m^2 for S2 correspondingly. Measurements of the liquid steel temperature and the oxygen activity therein have been made with use of Heraus Elektro-Nite equipment, specifically prepared for this purpose. After having the steel solidified in the mould and pouring system the two samples in form of slices of filtered and non-filtered steel have been collected from each melt for examination of steel pollution with the non-metallic inclusions and variations in the steel chemical composition. A percentage of a surface share of metallic inclusions has been used for analyses of steel pollution according to formula:

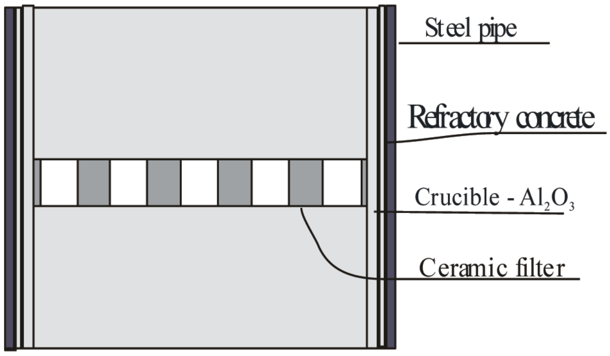

Fig. 1. Steel pouring system

Fig. 2. Position for process of steel filtrati in the atmosphere of argon

Fig. 3. Multi-hole ceramic filter

$$\eta_{NMI} = \frac{x_p - x_k}{x_p} \cdot 100\% \tag{1}$$

where: x_p – inclusion surface share (or inclusion number) before filtration,

x_k – inclusion surface share (or inclusion number) after filtration,

with use of the following intervals of inclusion diameters according to Ferret: 0.5÷2.5 μm, 2.6÷6.5 μm, 6.6÷15 μm, 15.6÷30 μm. The results of examination of steel chemical composition before and after filtration are shown in Table 1 while the results of examination of pollution with non-metallic inclusions are presented in Tables 2 and 3. The inclusions observed have shown differences in form and size. In melts deoxidized with aluminium the inclusions occur as individual ones and as clusters of irregular form and varying configuration. They are built of non-metallic phase (Al_2O_3) produced during the deoxidizing process.

TABLE 1

Results of chemical analysis of steel before and after filtration in the atmosphere of argon

	Chemical composition steel											
	Carbon, [C]		Manganese, [Mn]		Silicium, [Si]		Phosphorus, [P]		Sulphur, [S]		Aluminium, [Al]	
	%	η_C %	%	η_{Mn} %	%	η_{Si} %	%	η_P %	%	η_S %	%	η_{Al} %
1	2	3	4	5	6	7	8	9	10	11	12	13
1	$\frac{0.491}{0.490}$	**0.20**	$\frac{0.555}{0.560}$	**- 0.90**	$\frac{0.305}{0.298}$	**2.30**	$\frac{0.015}{0.015}$	**0.00**	$\frac{0.0170}{0.0175}$	**- 2.94**	$\frac{0.390}{0.415}$	**- 6.41**
2	$\frac{0.470}{0.480}$	**- 2.13**	$\frac{0.550}{0.550}$	**0.00**	$\frac{0.094}{0.091}$	**3.20**	$\frac{0.012}{0.012}$	**0.00**	$\frac{0.016}{0.017}$	**- 6.25**	$\frac{0.340}{0.350}$	**- 2.94**
3	$\frac{0.430}{0.430}$	**0.00**	$\frac{0.530}{0.530}$	**0.00**	$\frac{0.084}{0.086}$	**-2.40**	$\frac{0.013}{0.012}$	**7.70**	$\frac{0.023}{0.017}$	**26.08**	$\frac{0.387}{0.407}$	**-5.17**
4	$\frac{0.410}{0.410}$	**0.00**	$\frac{0.450}{0.450}$	**0.00**	$\frac{0.047}{0.046}$	**2.13**	$\frac{0.011}{0.010}$	**9.09**	$\frac{0.016}{0.021}$	**-31.25**	$\frac{0.354}{0.346}$	**2.26**
5	$\frac{0.510}{0.510}$	**0.00**	$\frac{0.530}{0.520}$	**1.89**	$\frac{0.059}{0.056}$	**5.01**	$\frac{0.012}{0.011}$	**8.33**	$\frac{0.022}{0.018}$	**18.20**	$\frac{0.324}{0.331}$	**-2.20**
6	$\frac{0.473}{0.471}$	**0.42**	$\frac{0.520}{0.520}$	**0.00**	$\frac{0.073}{0.072}$	**1.37**	$\frac{0.012}{0.012}$	**0.00**	$\frac{0.016}{0.016}$	**0.00**	$\frac{0.335}{0.357}$	**-0.59**
7	$\frac{0.440}{0.440}$	**0.00**	$\frac{0.480}{0.480}$	**0.00**	$\frac{0.057}{0.056}$	**1.75**	$\frac{0.014}{0.014}$	**0.00**	$\frac{0.021}{0.019}$	**9.52**	$\frac{0.395}{0.380}$	**3.79**
8	$\frac{0.495}{0.490}$	**1.01**	$\frac{0.540}{0.530}$	**1.85**	$\frac{0.060}{0.050}$	**16.6**	$\frac{0.011}{0.010}$	**9.09**	$\frac{0.017}{0.018}$	**-5.88**	$\frac{0.361}{0.367}$	**-1.66**
9	$\frac{0.410}{0.420}$	**-2.44**	$\frac{0.495}{0.495}$	**0.00**	$\frac{0.071}{0.070}$	**1.40**	$\frac{0.013}{0.012}$	**7.69**	$\frac{0.020}{0.021}$	**-5.00**	$\frac{0.349}{0.330}$	**5.44**
10	$\frac{0.460}{0.460}$	**0.00**	$\frac{0.466}{0.466}$	**0.00**	$\frac{0.040}{0.039}$	**2.50**	$\frac{0.013}{0.013}$	**0.00**	$\frac{0.022}{0.017}$	**22.73**	$\frac{0.328}{0.317}$	**3.25**

Description: numerator – element content in steel before filtration,
denominator – element content in steel after filtration,
η – rate of element content changes.

TABLE 2

Amount of non-metallic inclusion in steel filtered and unfiltered in the atmosphere of argon by Feret's diameter F_x

Test number	The number of all non metallic inclusions		The number of non metallic inclusions with the diameter F_x = 0.5 - 2.5. μm		The number of non metallic inclusions with the diameter F_x = 2.6 – 6.5. μm		The number of non metallic inclusions with the diameter Fx=6.5-15.5 μm		The number of non metallic inclusions with the diameter Fx=15.5-30.0 μm	
	Quantity, items.	η_{NMI}, %	Quantity, items.	η_{NMI}, %	Quantity, items.	η_{NMI}, %	Quantity, items.	η_{NMI}, %	Quantity, items.	η_{NMI}, %
1	2	3	4	5	6	7	8	9	10	11
1	441.5/430	**2.60**	213/209.5	**1.64**	137/170.5	**-24.50**	86/48,5	**43.60**	5,5/1,5	**72.73**
2	494,5/485,5	**1.82**	218.5/273.5	**- 25.17**	190.5/174	**8.66**	80.5/36	**55.28**	5/2	**60.00**
3	609/556	**8.70**	332/368.5	**- 10.99**	179.5/143.5	**20.06**	80/41	**48.80**	17.5/3	**82.86**
4	516.5/466	**9.78**	250.5/304	**- 21.36**	173.5/126.5	**27.09**	80.5/33	**59.01**	12/2.5	**79.17**
5	432/351.5	**18.63**	222/213	**4.05**	132/107	**18.94**	63.5/29	**54.33**	14.5/2.5	**82.76**
6	333/415.5	**-24.77**	204/274	**-34.31**	77/101.5	**-31.82**	47/36.5	**22.34**	5/3.5	**30.00**
7	448.5/381	**15.05**	296.5/241	**18.72**	91/114.5	**-25.82**	56/25.5	**54.46**	5/0	**100.00**
8	325/220	**32.31**	155/117	**24.52**	99/73.5	**25.76**	50/27.5	**45.00**	21/2	**90.48**
9	291/271.5	**6.70**	136/142.5	**-4.78**	80/99	**-23.75**	57/30	**47.37**	18/0	**100.00**
10	397.5/259.5	**34.72**	256/150.5	**41.21**	77/71	**7.79**	45.5/37	**18.68**	19/1	**94.74**

Description: numerator – number of non metallic inclusions in steel before filtration
denominator – number of non metallic inclusions in steel after filtration
η_{WN} – rate of non metallic inclusions number change.

TABLE 3

Area fraction of of non-metallic inclusion in steel filtered and unfiltered in the atmosphere of argon by Feret's diameter F_x

Test number	Superficial share of all non metallic inclusions		Superficial share of the inclusions with the diameter Fx=0.5-2.5 μm		Superficial share of the inclusions with the diameter Fx=2.5-6.5 μm		Superficial share of the inclusions with the diameter Fx=6.5-15.5 μm		Superficial share of the inclusions with the diameter Fx=15.5-30.0 μm	
	Superficial, %	η_{NMI}, %	Superficial, %	η_{NMI}, %	Superficial, %	η_{NMI}, %	Superficial, %	η_{NMI}, %	Superficial, %	η_{NMI}, %
1	2	3	4	5	6	7	8	9	10	11
1	0.702/0.449	**36.04**	0.032/0.033	**-3.13**	0.186/0.210	**-12.90**	0.422/0.178	**57.82**	0.062/0.028	**54.84**
2	0.625/0.403	**35.52**	0.034/0.042	**- 23.53**	0.244/0.201	**17.62**	0.294/0.129	**56.12**	0.053/0.031	**41.51**
3	0.799/0.432	**45.93**	0.049/0.057	**- 16.33**	0.176/0.164	**6.82**	0.338/0.182	**46.15**	0.236/0.029	**87.71**
4	0.683/0.299	**56.22**	0.046/0.046	**0.00**	0.177/0.129	**27.12**	0.302/0.104	**65.56**	0.158/0.020	**87.34**
5	0.561/0.272	**51.52**	0.035/0.036	**- 2.86**	0.132/0.116	**12.12**	0.248/0.095	**61.69**	0.146/0.025	**82.88**
6	0.394/0.311	**21.07**	0.027/0.028	**-3.70**	0.089/0.105	**-17.97**	0.209/0.148	**29.19**	0.069/0.031	**55.07**
7	0.413/0.242	**41.40**	0.037/0.037	**0.00**	0.090/0.124	**-37.78**	0.216/0.081	**62.50**	0.070/0.000	**100.00**
8	0.709/0.267	**62.34**	0.025/0.019	**24.00**	0.106/0.093	**12.26**	0.224/0.126	**43.75**	0.354/0.029	**91.81**
9	0.847/0.249	**70.60**	0.021/0.021	**0.00**	0.083/0.118	**-42.17**	0.404/0.110	**72.77**	0.339/0.000	**100.00**
10	0.773/0.280	**63.78**	0.034/0.026	**23.53**	0.070/0.092	**-31.43**	0.281/0.153	**45.55**	0.388/0.009	**95.10**

Description: numerator – surface share of non metallic inclusions in steel before filtration
denominator – surface share of non metallic inclusions in steel after filtration
η_{WN} – rate of the surface share change of non metallic inclusions.

3. Comparing the effectiveness of liquid steel filtration depending on the filter slenderness ratio

The influence of argon protective atmosphere has not caused substantial variations in the chemical composition of filtrated and non-filtrated steel. For S1 slenderness (λ =1.47) the increase has been observed in carbon contents of about η_C = -2.13% in the melt no. 2 and in sulphur contents in melts no. 1, 2 and 4. Instead, in three experimental melts, the decrease in phosphorus contents in the steel has been observed – especially in the melt no. 4 (η_P =9.09%). For S1 slenderness ratio (λ =4.44) the increase in sulphur contents has been observed in the steel after filtration for the melt no. 8 (η_S = -5.88 %) and insignificant increase in carbon contents for melt no. 9 (η_C = -2.44 %). Instead, in two experimental melts, similarly to the previous case, the decrease in phosphorus contents has been observed – especially in the melt no. 8 (η_P = 9.09 %). Results of examinations of the degree of steel pollution with non-metallic inclusions, and the effectiveness of steel filtration in the protective argon atmosphere for the ten experimental melt, are presented in Fig. 4-7.The numbers of non-metallic inclusions in the steel, in accordance with Feret diameters, are shown in Fig. 4. Instead, the surface share of non-metallic inclusions in each diameter interval presents Fig. 5. For S1 slenderness ratio (λ =1.47) only in one experimental melt (no. 5) the decrease in total number of non-metallic inclusions (η_{WN} = 18.63%) has been found, as well as decrease in all interval of Feret diameters. For S2 slenderness ratio (λ =4.44) in two melts (no. 8 and 10) the decrease in total number of non-metallic inclusions has been found (η_{WN} = 32.31% and η_{WN} = 34,72%), as well as in all intervals of Feret diameters. For S1 slenderness ratio (λ =1.47) the largest number of non-metallic inclusions eliminated has been for F_x diameter interval of 15.5÷30.0 μm in melt no. 3 (η_{WN} = 82.86%). In the remaining experimental melts the decrease has been found only in number of inclusions larger than 6.5 μm in diameter. For S2 slenderness ratio (λ =4.44) the largest number of non-metallic inclusions eliminated has been for F_x diameter interval of 15.5÷30.0 μm in melts no. 7 (η_{WN} = 100.00%) and no. 9 (η_{WN} = 100.00%). The number of non-metallic inclusions in lesser diameter intervals (below 6.5 μm) has increased to different degree depending on the melt number and Feret's diameter interval. As final result the total number of non-metallic inclusions in filtered steel has decreased to η_{WN} = 8.31% for S1 filter slenderness (λ =1.47) and to η_{WN} = 12.80% for S2 filter slenderness (λ =4.44) (Fig. 6).

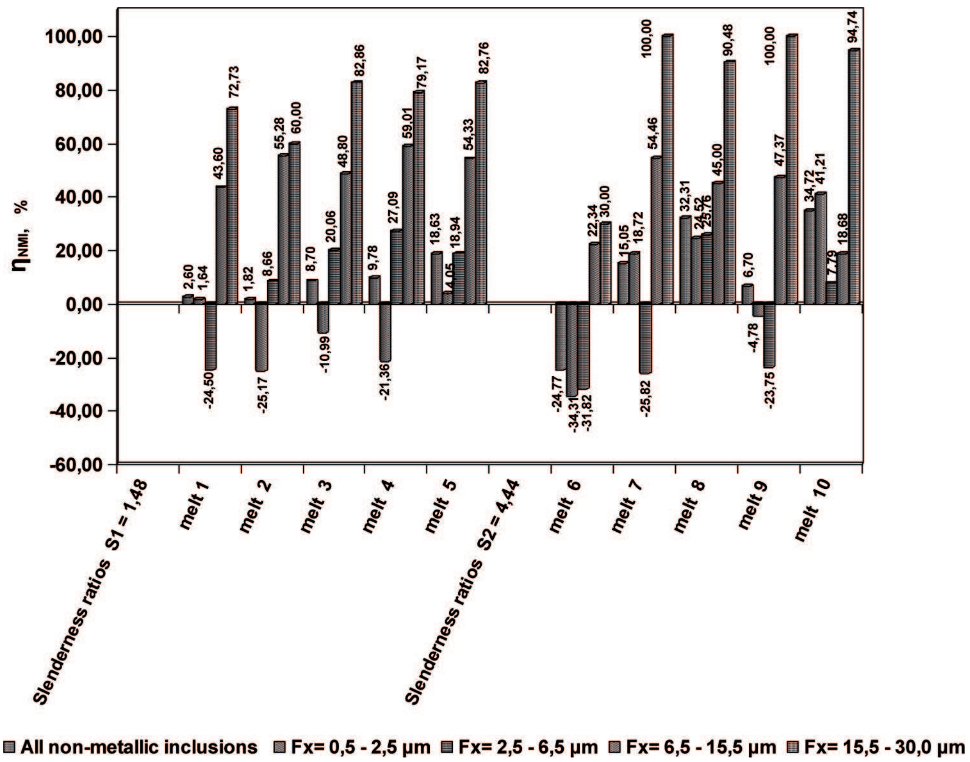

Fig. 4. The effectiveness of removing non-metallic inclusions as measured with the average rate of non-metallic inclusion number variation η_{NMI}, with division into inclusion size intervals according to F_x Feret diameters

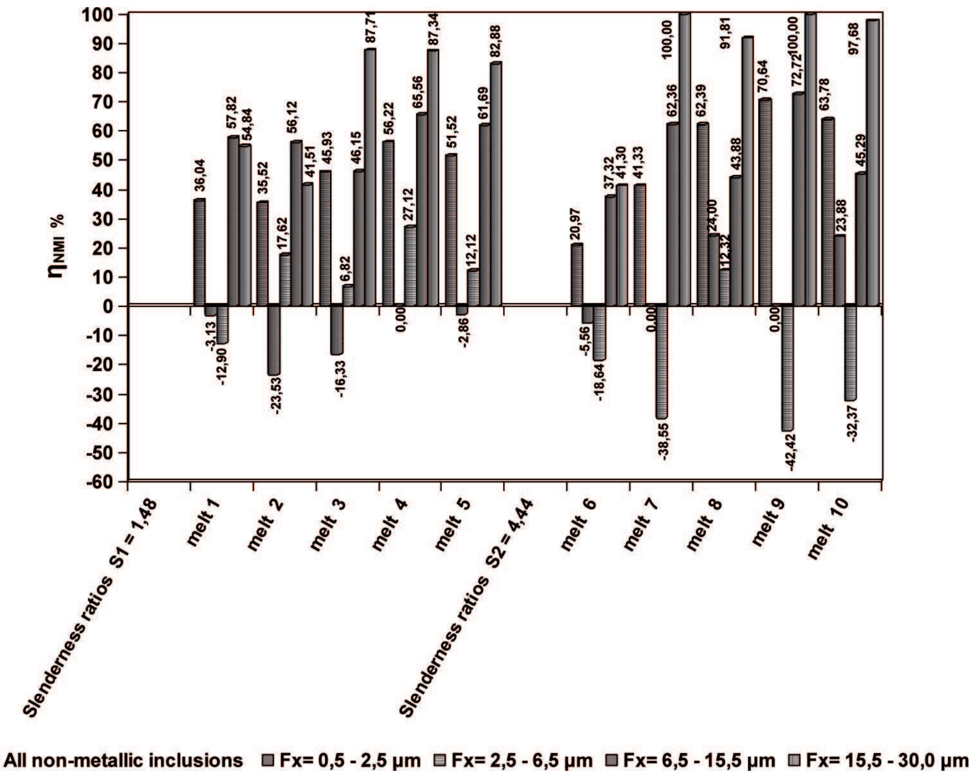

Fig. 5. The effectiveness of removing non-metallic inclusions as measured with the average rate of non-metallic inclusion superficial share η_{NMI}, with division into inclusion size intervals according to F_x Feret diameters

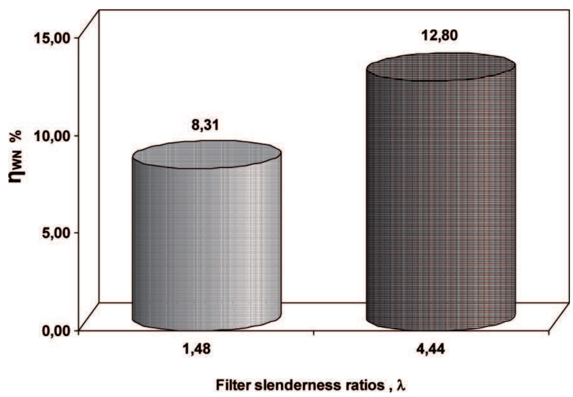

Fig. 6. The average rate of η_{NMI} non-metallic inclusion number variation for filter slenderness ratios of S1 (λ =1.47) and S2 (λ =4.44)

The effectiveness of liquid steel filtration in the protective argon atmosphere, measured as an average rate of variations of the non-metallic inclusion surface share in filtrated steel, as compared with the non-filtrated steel, has been also compared for both filter slenderness ratios. For S1 filter slenderness ratio (λ =1.47) only in one melt (no. 4) a decrease in total surface share of non-metallic inclusions has been discovered (η_{WN} = 56.22%), as well as inclusions in all Feret's diameter intervals.

Also for S2 filter slenderness ratio (λ =4.44) only in one melt (no. 8) a decrease in total surface share of non-metallic inclusions (η_{WN} = 62.39%) and inclusions in all Feret's diameter intervals has been found.

For S1 filter slenderness (λ =1.47) the largest number of eliminated non-metallic inclusions in F_x interval of 15.5÷30.0 μm has been obtained in melt no. 3 (η_{WN} = 87.71%), no. 4 (η_{WN} = 87.34%) and no.5 (η_{WN} = 82.88%). For S2 filter slenderness (λ =4.44) the largest number of eliminated non-metallic inclusions in F_x interval of 15.5÷30.0 μm has been obtained in melt no. 7 (η_{WN} = 100.00%) and no.9 (η_{WN} = 100.00%). In the remaining experimental melts a decrease, in all melts, has been found in the surface share of non-metallic inclusions only in diameters above 6.5 μm. Finally the total surface share of non-metallic inclusions in steel after filtration has been decreased to the value of η_{WN} = 45.05%

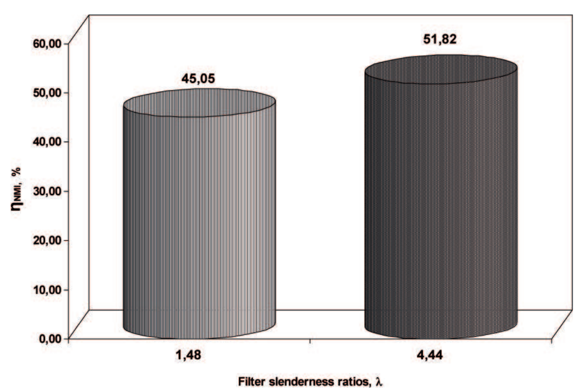

Fig. 7. The average rate of η_{NMI} non-metallic inclusion superficial share for filter slenderness ratios of S1 (λ =1.47) and S2 (λ =4.44)

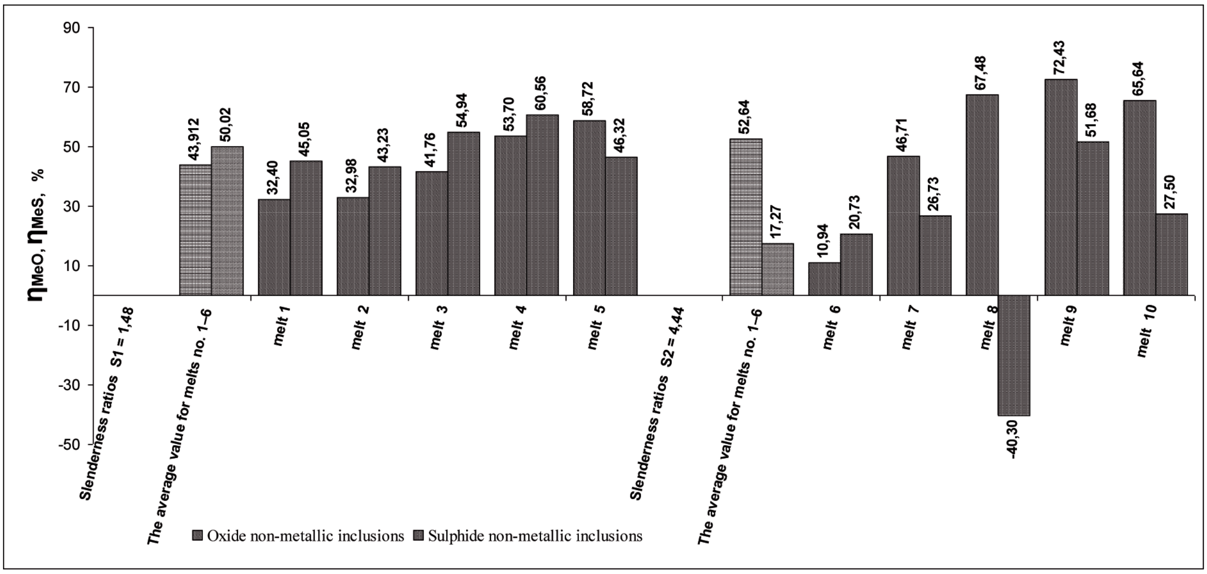

Fig. 8. The effectiveness of removing non-metallic inclusions, with the division into sulfide and oxide inclusions for ten experimental melts founded in the atmosphere of argon

for S1 filter slenderness ((λ =1.47) and η_{WN} = 51.82% for S2 (λ =4.44) correspondingly (Fig. 7). It means that besides the increase in inclusion number in filtrated steel of melt 6 (with smallest inclusions) the total inclusion surface, specified according to Feret's diameters, has been lower than that of inclusions identified in non-filtrated steel.

The estimation of effectiveness of liquid steel filtration has been also carried out in relation to oxide- and sulphide-inclusions (Fig. 8). The degree of surface share variation of the oxide non-metallic inclusions, as well as the sulphide ones, shows that the process of steel filtration with use of multi-hole ceramic filters is justified and effective, as much as possible. The highest degree of decrease (η_{MeO} = 58.72%) in the surface share of oxide non-metallic inclusions for S1 slenderness ratio (λ =1.47) has been obtained during filtration of melt no. 4, while the lowest one (η_{MeO} = 32.40%) during filtration of the melt no. 1. For S2 slenderness ratio (λ =4.44) the highest degree of decrease (η_{MeO} = 72.43%) in the surface share of oxide non-metallic oxide inclusions has been obtained during filtration of the melt no. 9, while the lowest one (η_{MeO} = 10.94%) during filtration of melt no. 6. For the sulphide non-metallic inclusions the highest degree of decrease in the surface share in relation to S1 slenderness filter (λ =1.47) has been noted in the melt no. 1 (η_{MeS} = 60,56%), while the lowest one (η_{MeS} = 43,23%) has been observed during filtration of melt no.2. For S2 filter slenderness (λ =4.44) the highest degree of decrease in surface share of sulphide non-metallic inclusions (η_{MeS} = 51.68%) has been found in melt no. 9, while the lowest one (η_{MeS} = -40.30%) has been obtained during filtration of melt 8. The microscopic image analyses of the samples

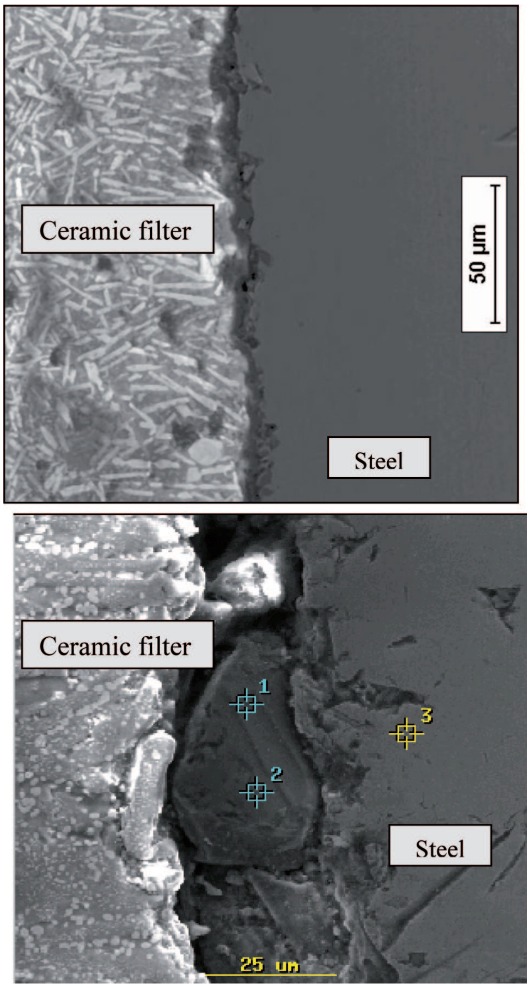

Fig. 9. Scaning pictures of interface partition filters ceramic – filtration steel of head no 1

investigated shows the oxide non-metallic inclusions, as well as sulphide ones, that in most cases are of globular or similar shape, occur in clusters, which are mutually connected to the lower or higher degree. The results of investigations of the division lines between the steel and the filter ceramics, as well as of border-line areas after filtration tests of melts no. 1 and 9 (deoxidized with use of aluminium) are presented, as exemplary data, in form of scanning images in Fig. 9 and 10. Solid products of the steel being deoxidized with aluminium, in form of Al_2O_3, have been identified on the surface of ceramic filter and in the border line area. Type of contact of the Al_2O_3 particle inclusion, as well as of particle cluster with the ceramic filter surface excludes chemical bonding and agglomeration of the contacting phases. The chemical composition of the identified products of process of steel deoxidizing with aluminium is proved by X-ray photos presented in Fig. 11 and 12.

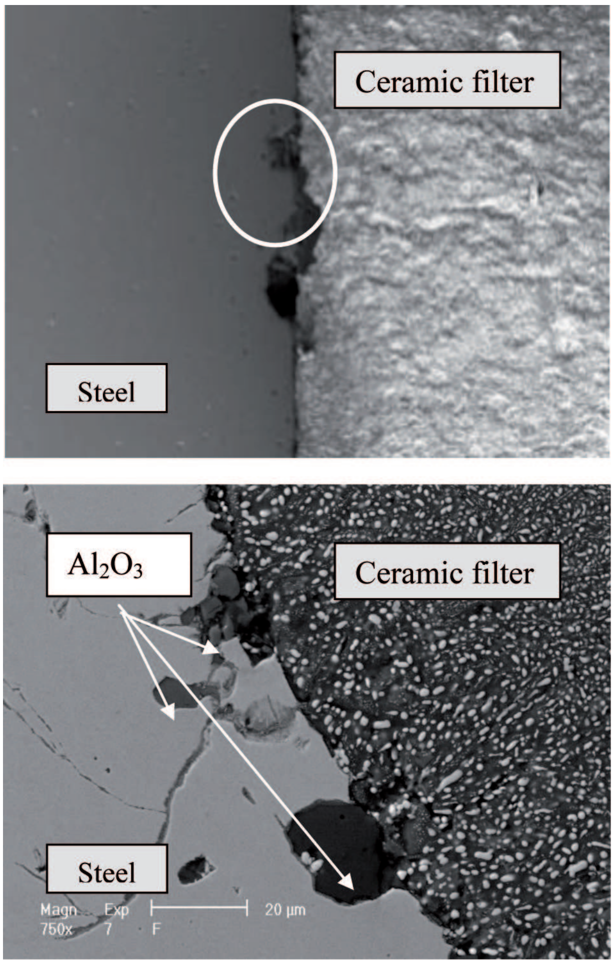

Fig. 10. Scaning pictures of interface partition filters ceramic – filtration steel of head no 9

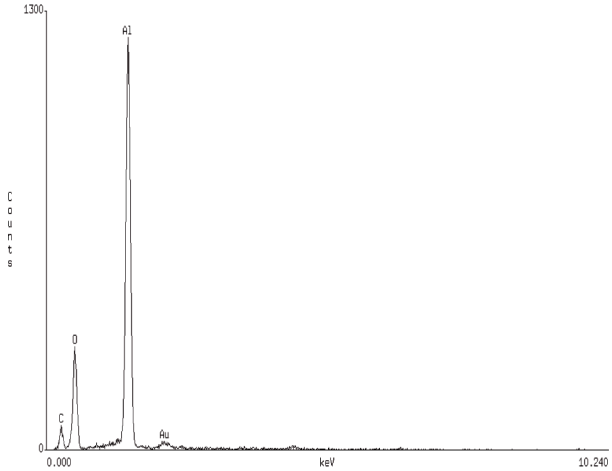

Fig. 11. X-ray photograph of non metallic inclusions chemical composition identified on the surface of a ceramic filter and in steel volume from melt 1

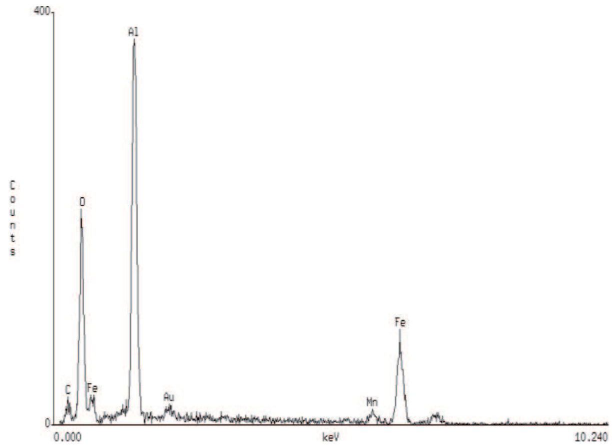

Fig. 12. X-ray photograph of non metallic inclusions chemical composition identified on the surface of a ceramic filter and in steel volume from melt 9

4. Summary and conclusions

The researches carried out constitute the fourth phase of planned research cycle concerning the process of liquid steel filtration with use of multi-hole ceramic filters in protective atmosphere and with variable filter slenderness (filtrating surface), carried out in the Metallurgy Department of the Silesian Technical University, and prove suggestions of authors of papers [3-11] about negative influence of the oxidizing air atmosphere at the effectiveness of steel filtration through ceramic filters. The results of researches carried, measured in form of η_{WN} index, prove that the use of protective atmosphere during the process of liquid steel filtration decidedly increase the process effectiveness. Its use during experiments carried out in laboratory condition has the aim to imitate as much as possible the condition of industrial refining in processing line of CC machine. The research results obtained evidence the substantial influence of the multi-hole ceramic filter slenderness at the results obtained. The steel cleaning effectiveness, as measured with average degree of the surface share variation, in relation to the whole range of inclusions, has decidedly increased and amounted respectively: η_{WN} = 45.05% for S1 filter slenderness (λ =1.47) and η_{WN} = 51.82 for S2 filter slenderness (λ =4.44). The total variation degree of inclusion number has also increased and amounted respectively η_{WN} = 8.31% for S1 filter slenderness (λ =1.47) and η_{WN} = 12.80 for S2 filter slenderness (λ =4,44). The increase in the number of non-metallic inclusions in filtrated steel for S2 filter slenderness (in melt no. 6), which relates to the smallest inclusions and finally the total inclusion number, has been probably caused by washing away the refractory lining of the newly formed crucible of the induction furnace. The above mentioned statement has been recognized to be highly probable due to the fact that such increase in total number of inclusions in the melt has been the only one instance during many years of researches of the liquid steel refining with use of multi-hole ceramic filters. In case of filtration of steel out of the non-metallic inclusions of larger size the results prove the earlier suggestions of authors of papers [9-11] about the highest effectiveness of this method of liquid steel refining in relation to the non-metallic inclusions of dimension above 6.5 μm.

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