Reliability of hot work steel suppliers for die casting dies

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1. Introduction

The selection of steel quality and steel supplier is the most important step in the manufacturing process of tools for die casting. The principle is that the wrong choice of steel in the initial stage is a step that can no longer be corrected throughout the production process.

As there are a number of suppliers on the Czech market who supply these materials, we have set ourselves the goal of trying to verify the extent to which these suppliers and their steels have complied with the requirements of the NADCA 207-2003 standard and the reliability of supply.

2. Experiment conditions

Five steel suppliers were selected for the testing program, one steel grade from each supplier. Four suppliers were from abroad, one supplier from the Czech Republic. Because the goal of the experiment was to verify the actual condition, and not the ideal condition, test materials were ordered through tool manufacturers without further specification. Only 2 suppliers provided a certificate with the sampling material, 3 suppliers skipped this step.

Due to the fact that the method of selection and the method of ordering did not allow for a retrospective check of the actual origin of the material, we do not name individual suppliers. There is a certain percentage of probability that even our intermediaries for the purchase of materials may not ensure the unmistakability of the supply.

3. Steel samples for testing

Supplier	Atest	C	Mn	Si	P	S	Cr	Mo	V
D1	Yes	0,38	0,40	1,10	-	-	5,0	1,30	0,40
D2	No	0,35	0,30	0,30	-	<0,003	5,0	1,35	0,45
D3 CZ	Yes	0,36	0,20	0,79	-	-	4,99	1,19	0,26
D4	No	0,38	-	1,00	-	-	5,30	1,00	0,40
D5	No	0,39	-	1,00	-	-	5,20	1,40	0,90

The actual chemical composition of the steel was monitored on a Metorex Arc-MET 900 spectrograph.

4. Experiment

The following tests were performed on each material sample:

Delivered condition tests

- hardness of the annealed structure
- evaluation of material cleanliness
- texture evaluation

Tests after heat treatment

- impact tests
- microstructure control

4.1. **Hardness of annealed structure**

Sample	Average HBW
D1	197
D2	171
D4 CZ	183
D4	201
D5	207

All samples had a ferritic structure with finely distributed spheroidized carbides. The hardness of the annealed structure 237 HBW, required in point I.B, was not exceeded by any of the suppliers. The microstructures of all suppliers corresponded to the AS2 rating according to Nadca 207-2003 at a magnification of 500x. Grain size and primary carbides were not evaluated.

4.2. **Evaluation of steel purity**

The ČSN 42 0471 standard for metallographic determination of non-metallic impurities was used to evaluate the purity of steels. The evaluation method is based on a comparison of the standard series of non-metallic inclusions specified in the standard at 100x magnification of non-etched surfaces.

Sample 1	Plane	Visual field	Linear oxides	Point oxides	Max. value
	Xz	1	2b	0	2
	Xz	2	0	2a	2
	Yz	1	0	1a	1
	Yz	2	0	2a	2
Average value			0,5	1,25	1,75

Sample 2	Plane	Visual field	Linear oxides	Point oxides	Max. value
	Xz	1	0	3a	3
	Xz	2	0	2a	2
	Yz	1	0	2a	2
	Yz	2	0	2a	2
Average value			0	2,5	2,5

Sample 3	Plane	Visual field	Linear oxides	Point oxides	Max. value
	Xz	1	3b	0	3
	Xz	2	0	3a	3
	Yz	1	4b	0	4
	Yz	2	4,5b	0	4,5

Average value	2,875	0,75	3,625

Sample 4	Plane	Visual field	Linear oxides	Point oxides	Max. value
	xz	1	1b	0	1
	xz	2	0	1a	1
	yz	1	0	2a	2
	yz	2	0	1a	1
Average value			0,25	1	1,25

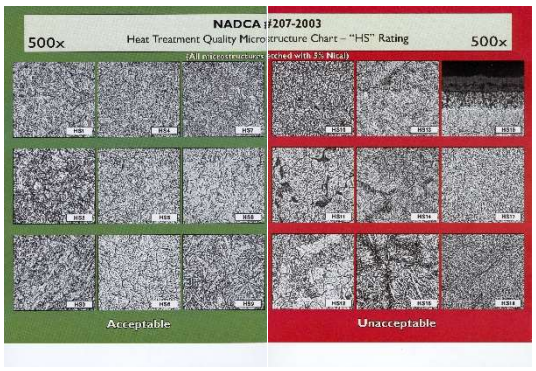
Sample 5	Plane	Visual field	Linear oxides	Point oxides	Max. value
	xz	1	0	2,5a	2,5
	xz	2	0	2,5a	2,5
	yz	1	3b	0	3
	yz	2	0	3a	3
Average value			0,75	2	2,75

According to NADCA specification 207-2003, the value of oxide inclusions must not exceed the number 2 for the quality "Premium", resp. 1.5 for "Superior" quality. From this point of view, 2, 3 and 5 did not comply.

4.3. **Heat treatment, microstructure check**

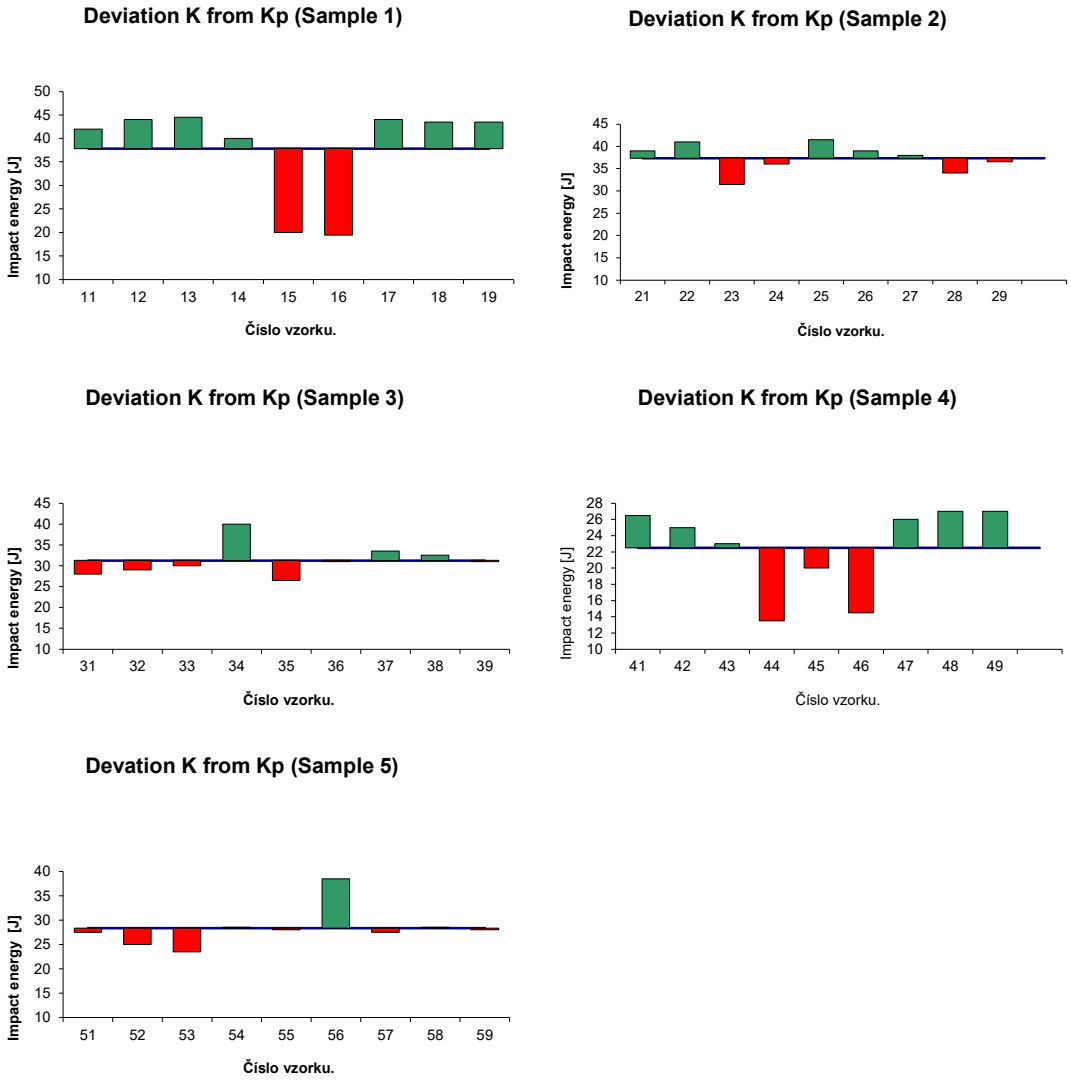
It was performed on samples for impact tests. The samples were hardened from 1030 °C, and tempered twice to a final hardness of 45 +1 HRc. The cooling rate during the cooling process was at least 30 °C/ min., resp. 10 bars overpressure.

All samples had a tempered martensite structure in the range according to Nadca 207-2003 - HS7 structure.



4.4. **Impact tests**

Impact tests for each set of samples were performed on Charpy's Hammer Leipzig 1971 at Technical University Liberec.



Impact values above the standard of 14 J were measured for all suppliers. An increased variance of values was found for samples 1 and 4. Due to the fact that it was not possible to determine the direction of the fibers from the supplied boards, it is possible that some samples, with the exception of D5, were also from the directions along the fibers.

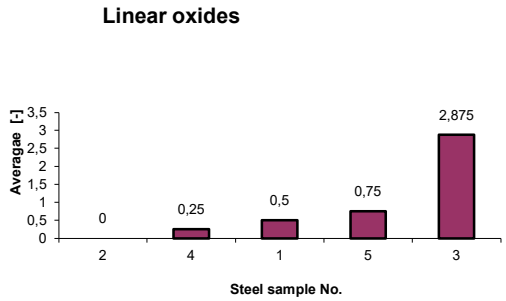
5. Comparison of individual steel samples

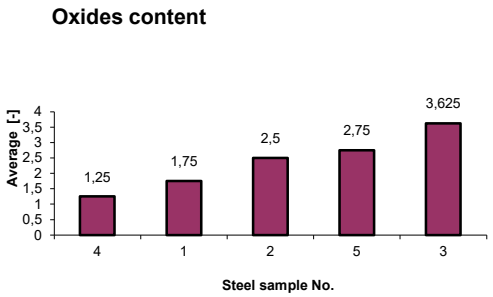
5.1. Chemical composition

Sample No.	Deviation from specification in %					
	C	Mn	Si	Cr	Mo	V
D1	-0,01	-0,09	0,09	-0,19	-0,03	-0,08
D2	0,02	v tol.	-0,07	-0,62	v tol.	-0,08
D3 CZ	-0,02	-0,16	-0,18	-0,11	0,03	-0,03
D4	v tol.	v tol.	v tol.	-0,13	v tol.	-0,05
D5	0,02	-0,17	-0,12	-0,4	0	-0,12

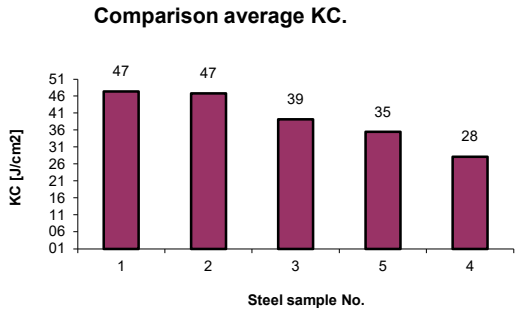
The chemical composition of various suppliers shows deviations from both the standard and the certificate. Due to the limited access to analytical methods, the content of P and S, ie elements that are very important for determining the quality, was not evaluated.

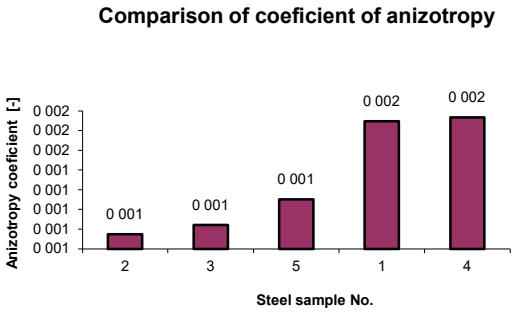
5.2. **Steel cleanliness**





5.3. **Impact tests**





6. **Conclusion**

The above assessment shows that the variance of values is significant especially for the purity of steel. More than half of the delivered samples did not meet this parameter. Although the results of the impact tests reached relatively good values, it should be noted that these are cross-sectional values from a single measurement point. That is, the effect of impurities is manifested only in the actual function of the die, when there is a complex loading of the material by cyclic thermal fatigue at elevated temperatures. Defects initialized on impurities can mean not only a reduction in die life or premature crack formation and propagation, but above all catastrophic damage to the dies.

It is obvious that even if there is no 100% certainty about the origin of the tested steels, its quality is a very variable matter and the supplier cannot be relied on without entry control. The basic condition for the material to meet the requirements is that it undergoes a production process of remelting under slag, or even better by vacuum remelting. Sample No. 3 shows that it is probably a non-remelted steel, with a high content of impurities, completely unsuitable for die-casting parts.

The evaluation also shows that the mere assessment of impact strength is not an unambiguous criterion, and that the material must be evaluated comprehensively as set out in NADCA 207-2003. Only in this case can significant reliability of material selection and control at the inlet be achieved, and maximum die life safety can be secured.