THE DETERMINATION OF THE PROPERTIES OF FOUNDRY SANDS WITH DYNAMIC SPECTRAL ANALYSIS

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The granulometric properties of foundry sands with different grain sizes and granular structures were determined using standard grading analysis and dynamic spectral analysis. The results of the two analyses were compared and the reasons behind their differences were revealed.

Keywords: sieve analysis, granulometric properties, spectral analysis, foundry sand

INTRODUCTION

One of the most important properties of foundry sands is grain size, along with grain distribution. These granulometric properties are taken into consideration in case of buying basic sand and are continuously monitored by foundries during the manufacturing process. The determination of these properties has various methods, including dry dispersion and laser diffraction [1].

In case of dry dispersion, two methods can be distinguished: conventional granulometric analysis or sieve analysis and grain distribution determination via spectral analysis. Classification using spectral analysis counts as a fairly new method in case of foundry sands. The method of operation differs from the operation of standard sieve analysis. In order to achieve this economically and efficiently, foundries should stay up-to-date with the latest technologies and apply these if possible.

1. STANDARD SIEVE ANALYSIS

50 g sand samples were used for standard sieve analysis. The various sieve sizes used for the measurements are summarised in Table 1.

Numerous parameters of the various sand samples can be determined based on the evaluation of the data from the sieve analysis. Some of these parameters can be calculated from the cumulative curve of the sample [3]. A cumulative curve and its evaluation can be seen in Figure 1.

The average grain size D (mm) and the degree of uniformity E (%) can be determined based on the cumulative curve, which are related to the quality of sands with respect to the grain distribution. The average grain size value equals with the theoretical size of the sieve on which 50% of the analysed sand passes through and 50% is retained. Equality ratio can
be determined based on the mean particle size. In this case, a value 1/3 smaller than the mean particle size at a certain point and a value 1/3 higher than the mean particle size at another point are determined. The difference of these values is the equality ratio in percentages [3].

Table 1
Sieve sizes for standard sieve analysis [2]

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>1.400 &lt;</th>
<th>1.400 – 1.000</th>
<th>1.000 – 0.710</th>
<th>0.710 – 0.500</th>
<th>0.500 – 0.355</th>
<th>0.355 – 0.250</th>
<th>0.250 – 0.180</th>
<th>0.180 – 0.125</th>
<th>0.125 – 0.090</th>
<th>0.090 – 0.063</th>
<th>&lt; 0.063</th>
</tr>
</thead>
</table>

Figure 1
A cumulative curve and its evaluation [3]

2. THE DETERMINATION OF GRAIN STRUCTURE WITH SPECTRAL ANALYSIS

Static and dynamic spectral analysis can be distinguished. The static spectral analysis (Standard ISO 13322-1) is based on the operating principles of a microscope. During the analysis, the grains are spread on a holder and photos are taken to determine the size and
shape of the grains. Gravity evening the sand grains makes this method advantageous as the particles can be studied with a depth of field (\(\varepsilon\)) well-controlled by the optics. Thus, the needle-like shapes of sand grains can be properly measured and graded as well. The disadvantage of static spectral analysis is that only a small portion of sample can be analysed. Averagely only a few 1000 particles can be photographed at once which makes the precision of the results restricted and the evaluation is aggravated by the overlapping particles. The schematic structure of spectral analysis can be seen on Figure 2.

![Figure 2](image.png)

*Figure 2*

*The theoretical structure of spectral analysis [1]*

During dynamic spectral analysis (Standard ISO 13322-2), pictures are taken of freely moving sand particles by a fixed camera. Based on the 2D projection of the particles their sizes are determined. The schematic structure of dynamic spectral analysis can be observe on Figure 3 [1].

![Figure 3](image.png)

*Figure 3*

*The theoretical structure of dynamic spectral analysis [1]*
3. The Fritsch Analysette 28 Dynamic Image Sizer

*Figure 4* shows a Fritsch Analysette 28 equipment. This instrument operates on the operating principles of dynamic spectral analysis. It is suitable for the determination of the size and shape of sand grains. The pictures taken by the camera can be evaluated with the help of the Image Sizing Software (ISS). Changing the photo/second ratio is possible to increase the precision of the measurement. The grain size can be measured from 20μm to 20 mm. The shapes and shape factors of the sand grains can be determined based on the pictures taken by the camera [4] [5].

![Fritsch Analysette 28 equipment](image)

*Figure 4*

A Fritsch Analysette 28 equipment [4]

4. The Comparison of the Results of the Standard Sieve Analysis and the Dynamic Spectral Analysis

Granulometric properties of sand samples with various grain sizes and grain distributions were measured with both standard sieve analysis and an Analysette 28 equipment. The measurements were carried out at the sand laboratory of the Institute of Foundry Technology at Freiberg University. The aim of the measurements was to determine the differences between the granulometric parameters measured with standard sieve analysis and dynamic spectral analysis.

The average grain sizes which were determined with both standard sieve analysis and Analysette 28 are summarised in Table 2.
The Determination of the Properties of Foundry Sands with Dynamic Spectral Analysis

The average grain sizes determined with standard sieve analysis and Analysette 28

<table>
<thead>
<tr>
<th>Sand sample</th>
<th>Average grain size (mm), Standard sieve analysis</th>
<th>Average grain size (mm), Analysette 28</th>
<th>Deviation from sieve analysis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-70</td>
<td>0.20</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td>FMX-40</td>
<td>0.38</td>
<td>0.35</td>
<td>7.89</td>
</tr>
<tr>
<td>H32</td>
<td>0.30</td>
<td>0.28</td>
<td>6.67</td>
</tr>
<tr>
<td>Szerb 0.24</td>
<td>0.24</td>
<td>0.20</td>
<td>16.67</td>
</tr>
<tr>
<td>GBM 45</td>
<td>0.37</td>
<td>0.33</td>
<td>10.81</td>
</tr>
<tr>
<td>Regenerated fine sand</td>
<td>0.25</td>
<td>0.23</td>
<td>8.00</td>
</tr>
<tr>
<td>SH 32</td>
<td>0.39</td>
<td>0.38</td>
<td>2.56</td>
</tr>
<tr>
<td>SH 32 regenerated</td>
<td>0.36</td>
<td>0.33</td>
<td>8.33</td>
</tr>
<tr>
<td>SH 34</td>
<td>0.23</td>
<td>0.21</td>
<td>8.70</td>
</tr>
</tbody>
</table>

The deviation of average grain size values calculated from the cumulative curves representing the granulometric properties measured with standard sieve analysis and Analysette 28 were between 0–17%. The average grain size values determined with dynamic spectral analysis were lower than the average grain size values determined with standard sieve analysis in almost all cases.

The degrees of uniformity determined with both standard sieve analysis and the Analysette 28 equipment are summarised in Table 3.

The degree of uniformity values determined with standard sieve analysis and Analysette 28

<table>
<thead>
<tr>
<th>Sand sample</th>
<th>Degree of uniformity (%), Standard sieve analysis</th>
<th>Degree of uniformity (%), Analysette 28</th>
<th>Deviation from sieve analysis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-70</td>
<td>73</td>
<td>71</td>
<td>2.74</td>
</tr>
<tr>
<td>FMX-40</td>
<td>70</td>
<td>60</td>
<td>14.29</td>
</tr>
<tr>
<td>H32</td>
<td>70</td>
<td>71</td>
<td>1.43</td>
</tr>
<tr>
<td>Szerb 0.24</td>
<td>64</td>
<td>52</td>
<td>18.75</td>
</tr>
<tr>
<td>GBM 45</td>
<td>70</td>
<td>54</td>
<td>22.86</td>
</tr>
<tr>
<td>Regenerated fine sand</td>
<td>90</td>
<td>65</td>
<td>27.78</td>
</tr>
<tr>
<td>SH 32</td>
<td>81</td>
<td>68</td>
<td>16.05</td>
</tr>
<tr>
<td>SH 32 regenerated</td>
<td>86</td>
<td>68</td>
<td>20.93</td>
</tr>
<tr>
<td>SH 34</td>
<td>81</td>
<td>57</td>
<td>29.63</td>
</tr>
</tbody>
</table>

The deviation of the degrees of uniformity calculated from the cumulative curves representing the granulometric properties measured with standard sieve analysis and Analysette 28 were between 2–30%. The degrees of uniformity determined with dynamic
spectral analysis were lower than the degrees of uniformity determined with standard sieve analysis in almost all cases.

The reasons behind the deviations can be attributed to the inhomogeneity of the sand samples and the differences between the two measuring methods. Sand grains occur in various, complex shapes, the size of which cannot be characterised with only one parameter. The shape of grain particles can be spheroidal, flat or completely irregular. The more complex the shape is, the more difficult it is to describe it. Thus, the particles are normally characterised by the diameter of a theoretical sphere during spectral analysis that is similar to the examined particle from a certain aspect. This parameter is called geometrical diameter in case of geometrical similarity and equivalent diameter in case of any other physical parameters [6].

Values determined using equivalent diameter during spectral analysis might drastically deviate from values determined by standard sieve analysis. 3–7% deviation is the technological tolerance of the sieve sizes used for sieve analysis. However, certain holes might be 50% larger than the standardised size. The shape of the particles might lead to miscalculations as well. The flatter or more misshaped the particle is, the more likely it is retained on the sieve. Furthermore, elongated (acicular shape) particles with smaller size than length may fall through sieves [6]. The cumulative curves of sample H32 were recorded using the data from both standard sieve analysis and the Analysette 28 equipment. The difference between the cumulative curves from the two measurements can be seen in Figure 5.

![Figure 5](image)

*Figure 5*

*The cumulative curves for sample H32*

The deviation between the average grain size values and the differing slopes of the two cumulative curves can be observed on *Figure 5*. The result of these differences is the deviation of the degrees of uniformity. The reasons behind the deviations can be attributed...
to the various shapes of the sand samples and the differences between the two measuring methods. The differences between sand particles can be determined by the photos of dynamic spectral analysis. However, this method of determination is rather subjective. A photo of sample H32 can be examined on Figure 6, while a photo of sample SH34 can be seen on Figure 7.

Figure 6
Photo of sample H32 during dynamic spectral analysis

Figure 7
Photo of sample SH34 during dynamic spectral analysis
CONCLUSION

Based on the comparison of the data determined with standard sieve analysis and dynamic spectral analysis it can be concluded that both the average grain size values and the degrees of uniformity differ. This result is supported by data from international literature [7]. Fast measurements make the usage of Analysette 28 advantageous, especially economically, but in case of sands with elongated, flat or misshaped particles deviations should be expected which may be compensated using a suitable software. The shapes, shape factors and further morphological parameters of the base sand can be determined using the photos from dynamic spectral analysis. The safety of the production can be improved with such further details which can provide basis for determining subsequent relations as well.

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http://www.retsch-technology.de/de/rt/applikationen/fachberichte/