METABK 54(1) 247-250 (2015)
UDC – UDK 669.01.18:669.18.047:62.001.57=111

MODELLING OF OUTBURSTS AND EJECTIONS OCCURRENCES DURING STEEL PRODUCTION

Received – Primljeno: 2014-04-16
Accepted – Prihvaćeno: 2014-09-09
Preliminary Note – Prethodno priopćenje

The application of small industrial cameras linked to a computer to create models for monitoring of adverse events in the steel making process is referenced. Presented models were created by analyzing video recordings that were captured in areas that could directly threaten human life. In laboratory conditions it is possible to analyze the recorded data and then already known mathematical methods are used to evaluate phenomena that are characterized in operating conditions by rapid pace and their monitoring on site is difficult and dangerous.

Key words: steel making process, information technology, create models, ejection, outburst

INTRODUCTION

Current new information technologies allow to capture and record data of production processes even in difficult operating conditions in real time. A subsequent analysis and evaluation of measurement data, directly on site or in the laboratory can bring new knowledge about these phenomena. [1-6]. One such example, described in this article is the use of small industrial cameras followed by the creation of computer models for analysis of ejection and outbursts in the steel making process. Videos of these phenomena could be closely analyzed in laboratory conditions and then evaluated using already known mathematical techniques. Steelmaking processes are well described already; therefore this article focuses only on problem areas that bring new insight into the observed phenomena [7].

THE EJECTION

The term Ejection in this context represents irregular splatter of smaller or larger particles of metal and slug blasting from the neck of the converter. Ejection may be caused by several factors, namely:

1. by explosive contact of reacted and unreacted part of the melt,
2. due to improper converter form,
3. due to poor circulation or uneven melt,
4. due to resonance motion of the melt and gas,
5. due to resonance transverse waves in the converter,
6. due to shape of the workspace of the converter, when there is no consistent depth of the melt, the amount of workspace and decarburization rate.

M. Malindžáková, A. Rosová, J. Futó - Technical University of Košice, BERG Faculty, Košice, Slovakia
V. Baranová, VŠB – Technical University of Ostrava, Fakulta of Mechanical Engineering, Czech Republic

The ejection causes a decrease in the yield of steel (0,5 to 1 %), changes in the thermal balance of melt during refining, changes in the final temperature of the steel and there are increases in crust grows on the mouth of the throat of the converter. The ejection is visually identifiable as a phenomenon in which the converter appears in flames, and there are splashes of molten slag and metal from the throat of the converter (Figure 1) [8, 9].

THE OUTBURST

In the steel making process, oxygen is delivered into molten iron through a nozzle in the form of gas flow for decarbonisation. Contemporary authors state that the peak of the flow causes rapid decarbonisation of slug in the final stage of the process. Gas flow detaches the liquid which then spatters in metal droplets. This phenomenon is called an outburst, causing operational problems that lead to a reduction in productivity and metal yield. Therefore it is desirable to reduce the number of out-

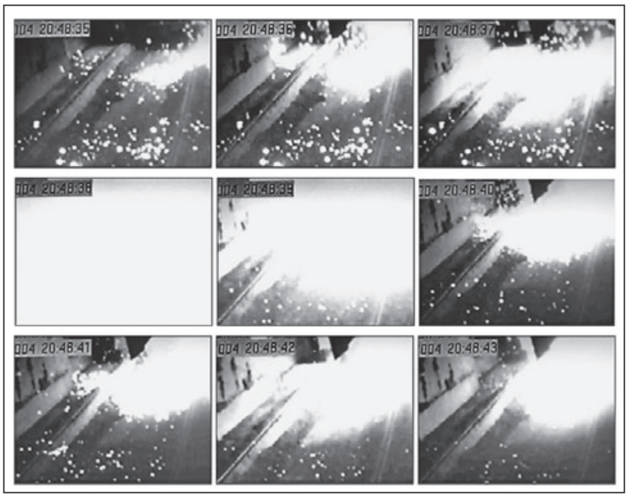

Figure 1 The ejection sequence (duration 8 s)

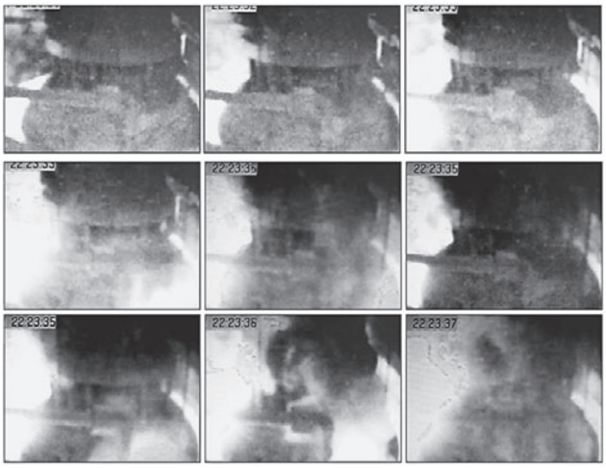

Figure 2 The outburs sequence (duration 6 s)

bursts. Visually the outburst can be observed as flames outburst from the converter (Figure 2) [8, 9].

MODELING AND DISCUSSION

Both outburst and ejection negatively affect the effectiveness of the steelmaking process [8, 9]. The data analysis was based on the assumption that these phenomena are „failures" that result from some variables „that are beyond our control" during steel refining and that they negatively influence the process. The whole process of steel refining has been recorded by cameras CAM1 and CAM2 (Figure 3). The observed adverse events were recorded and the necessary information was evaluated so that we can determine „the duration until the failure occurs" or „the duration of failure". The camera placed below the converter monitored ejections, whilst the camera positioned above the converter monitored the outburst. The starting point for analysis was the record of 31 subsequent casting campaigns. Given the amount of data retrieved from these records, we can assume that the file provides sufficiently substantial data sample that can be evaluated using several statistical methods. For both observed phenomena we recorded two of the variables, namely:

- the time until the phenomenon started,
- the duration of the phenomenon.

Both these phenomena are characterized by a random variable - time.

In Figure 4 are graphs showing the number of outbursts and ejections in each casting campaign. It is important, that the number of outbursts is more than 2,5 times grater than the number ejections [10, 11].

TIME UNTIL THE BEGINNING OF AN OUTBURST

The analyzed file contained 290 duration values from the beginning of an outburst. These values were then divided into nine classes, with class characters in the range from 25,44 up to 416,56 seconds. The outburst is characterised by a large number of short time intervals, where the first three classes represent more than 92 % of the total value and the remaining 6 classes represent the 8 % of the value. Histogram of the proliferation from the beginning of an outburst is shown in Figure 5.

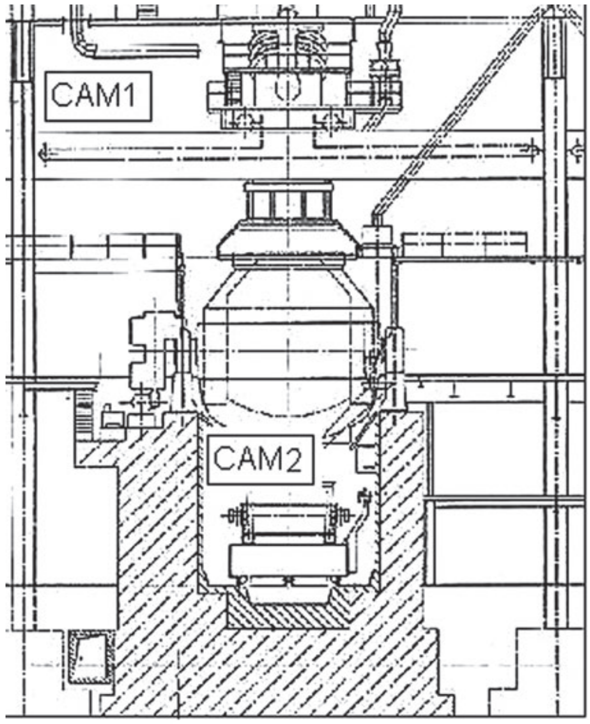

Figure 3 Deployment of cameras CAM1 and CAM2

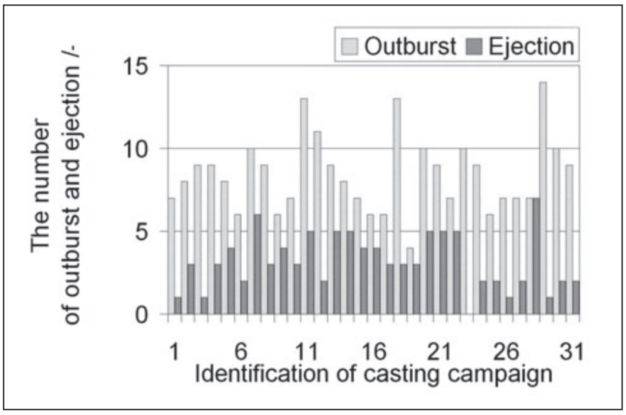

Figure 4 The number of outbursts and ejections in casting campaign

In quantitative terms, if the frequency values for all times until the outbursts failure were the same, there would be zero variability. In the examined values, the fluctuations of duration-until-failure values for each class are visible. The variability of these values is expressed by distribution of their frequencies.

TIME UNTIL THE START OF AN EJECTION

A total of 129 values until the beginning of an ejection for 31 casting campaigns were divided into 8 classes, with class characters in the range from 49 to 735 seconds.

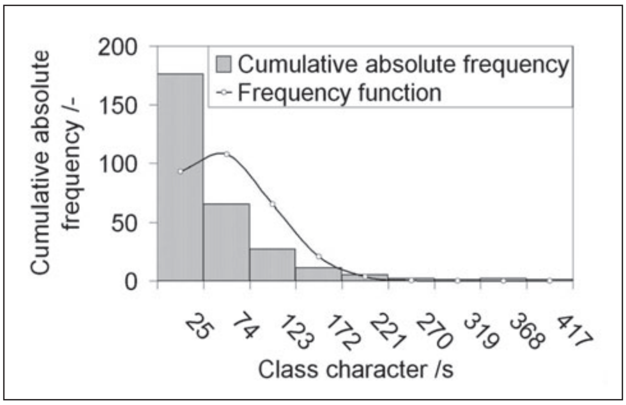

Figure 5 Histogram of the absolute frequency and frequency function of time until an outburst begins

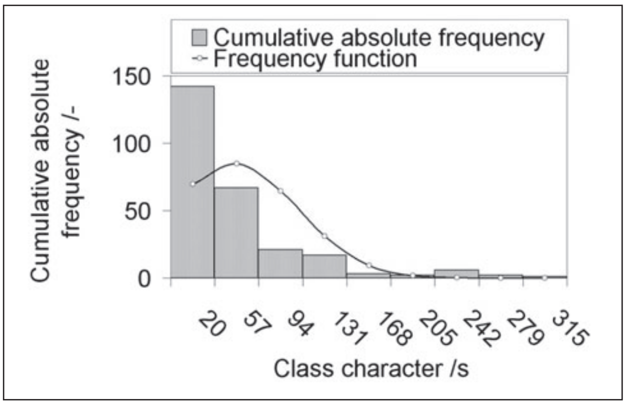

Figure 7 Histogram of the absolute frequency and frequency function of the time until an outburst begins

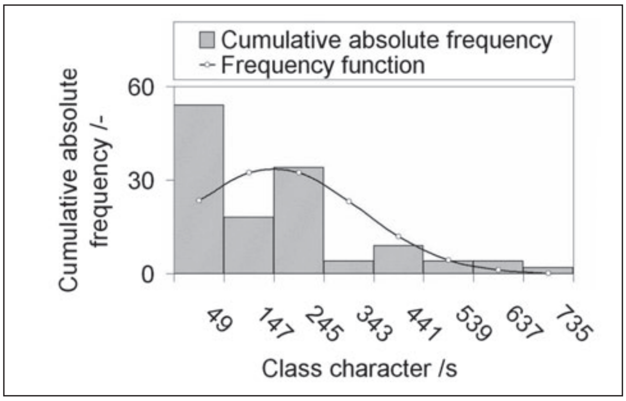

Figure 6 Histogram of the absolute frequency and frequency function of the time until an ejection begins

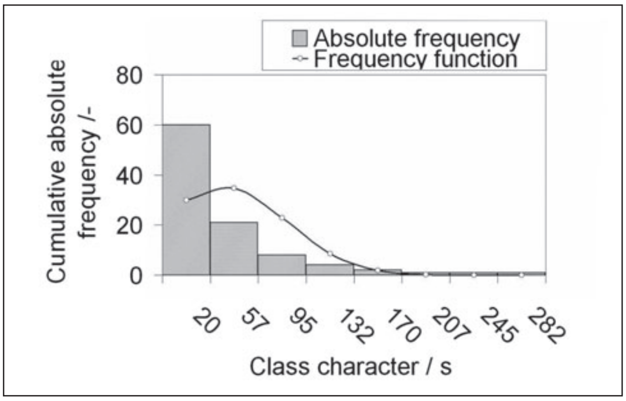

Figure 8 Histogram of the absolute frequency and frequency function of the time of an ejection

From Figure 6 it is evident that the time interval to outburst start varies several times. The frequency of this phenomenon is demonstrated by the large number of short time intervals, where the first three classes are represented by almost 82 % of the total number of times to ejection failure and remaining five classes consisted of 18 % of the total number of times to ejection failure.

DURATION OF AN OUTBURST

The frequency for this phenomenon is mainly reflected by a large number of short time intervals, where the first three classes represent almost 88 % of the total duration of failure for outbursts and the remaining six classes represented only 12 % of the total number of duration of failure for outbursts (Figure 7).

THE DURATION OF AN EJECTION

The duration of the ejection from 31 casting campaigns were divided into 8 classes, with class characters are in the range from 19,75 to 282,25 seconds. From the Figure 8 it is clear that the phenomenon is again concentrated in the first three time classes, where the first three classes are represented by almost 91 % of the total durations of the ejection failure and the remaining five classes representing merely 9 % of the total. The duration of the disorder for ejection compared with the class mark time to failure for outbursts is 1,5 times longer [12].

CONCLUSION

The processing of the two sets of data shows that these are two distinct phenomena in the frequency of their occurrence in the process, as well as in their duration. Ejection process is less favorable in terms of manifestation and most often occurs in the interval from the end of the third minute to the end of the sixth minute. During these three minutes occurs the ejection of duration from 25 seconds to about three minutes. Frequently, however, it takes 1 minute. The nature of the disorder depending on the intensity could result in the disruption of the casting, and to associated losses. Outburst, unlike ejection, is manifested by much more frequent and faster occurrences. The most frequently seen are short outburts intervals ranging from thirty to ninety seconds. In comparison to ejection there is much more dynamic manifestation, with much shorter duration occurring, however, more frequently.

Compared with the total duration of „failure“ for outburts the value of the class character is almost comparable. These quantitative relations between both monitored failures show a clear box and whiskers plot (Figure 9).

It is clear that for the quality of the steelmaking process it is important to keep the process without ejection, since ejections affect the terms of the effectiveness of the process so significantly. In terms of production it is important to first control the phenomenon, which is less

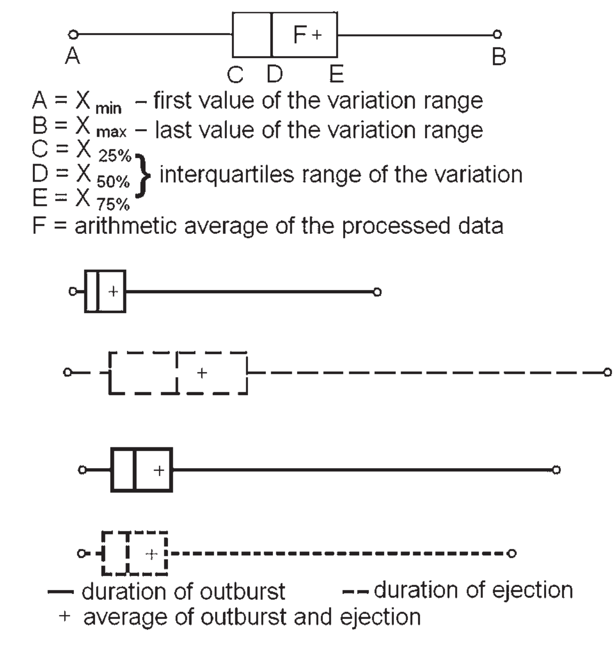

Figure 9 Box and whiskers plot

favorable, that is the ejection, which is slower and less numerous. Given the possibility of preventing or predicting ejection, it is necessary to further study and analyze it on the basis of experiments carried out by using indirect methods, such as acoustic or visual manifestation of ejection to predict and subsequently manage it.

Finally, it is important to note that the main aim of the article is mainly to describe the possibility of different models creation, from data acquired in the most demanding conditions and does not address the forecasting, or the suppression of these adverse events. The design and technological solutions to eliminate these phenomena are already known and often used.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the grants VEGA No. 1/0216/13, VEGA No. 1/0729/12, VEGA No. 1/0552/14, VEGA No. 1/0295/14.

REFERENCES

[1] D. Baricová, A. Pribulová, P. Demeter, B. Buľko, A. Rosová: Utilizing of the metallurgical slag for production of cementless concrete mixtures, Metalurgija, 51 (2012) 4, 465-468.

[2] I. Leššo, P. Horovčák, P. Flegner: Evaluation of sensor signal processing methods from the aspect of information theory, AT&P Journal, 11 (2004) 4, 70-73.

[3] J. Kačur, M. Durdán, M. Laciak: Utilization of the PLC as a web server for remote monitoring of the technological proces. In: ICCC'2013: 14th International Carpathian Control Conference, Rytro, Poland. Piscataway: IEEE, 2013, 144-149.

[4] V. Mihalič: Steel making II. Vydavateľstvo technickej a ekonomickej literatúry, Bratislava, 1983.

[5] V. Baranová: The impact of Quality of Input Material for the Converter Process, Kosice, Technicka univerzita, F BERG, Diploma thesis, 2010.

[6] Ľ. Floreková: Methods of statistical quality assessment - SPC. Acta Montanistica Slovaca, 1 (1998), 1-20.

[7] M. Laciak, M. Durdán, J. Kačur: Utilization of indirect measurement in the annealing process of the steel coils, Acta Metallurgica Slovaca, 18 (2012) 1, 40-49.

[8] J. Kačur, M. Laciak, M. Durdán: Remote monitoring and control of the UCC process. 1 elektronický optický disk (CD-ROM). In: ICCC'2011: proceedings of the 12th International Carpatian Control Conference, 2011, Velké Karlovice, Czech Republic. IEEE, 2011, 180-184.

[9] I. Leššo, F. Krepelka, P. Horovčák, J. Terpák, M. Benková, P. Flegner, G. Bogdanovská, D. Bednárová, M. Šujanský, M. Hudymáčová, B. Stehlíková: Research for exact methods of assessing the effectiveness and quality of the process of rocks disintegration by rotary drilling, Final Report for the duration of the project: No. project: 1419407/ - Košice: TU - 2009.

[10] A. Rosová: Indices system design of distribution logistics, transport logistics and material flow as parts of controlling in enterprise's logistics. Acta Montanistica Slovaca. 15 (2010) 1, 67-72.

[11] B. Stehlíková, K. Kostúr, M. Jaco: Technological process distortions identification by digital cameras taken. In: ICCC '2005. Volume 1. Miskolc: University of Miskolc, 2005, 355-360.

[12] J. Tůma, R. Wagnerová, R. Farana, L. Landryová: Fundamentals of Automation, 1. edition. Ostrava, VŠB-TU Ostrava, 280 p.

Note: The English Language translation was done by L. Pivka, Kosice, Slovakia