

An Online Fault Pre-warning System of the Rolling Mill Screw-down Device Based on Virtual Instrument

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Abstract: A traditional off-line screw-down monitoring system performs not well on real-time signal analysis or process, which cannot provide simultaneous fault pre-warning either. A diagnostic monitoring system as well as a remotely accessible graphic user interface is presented in this paper. The main objective of this work is to develop an online and available technique for monitoring the kinetic, hydrodynamic and electrical parameters of the rolling mill screw-down device, and analyze these figures to support online fault pre-warning. A series of transducers are installed in suitable locations to measure parameters decreed above including the vibration acceleration of a rolling mill stand, the rolling force of a screw-down device, the stroke of a hydraulic cylinder, the system source pressure, the in-cylinder stress and the output value of an electro-hydraulic servo valve. An industrial personal computer picks up the information transformed by an extra high-speed data acquisition board embedded inside, processes the signals via a software designed by means of Laboratory Virtual Instrument Engineering Workbench (LabVIEW) and indicates fault conditions through the graphic user interface. Besides, the data of the overall system can be published over the Internet using LabVIEW Web Server capabilities. The results of experiments suggest that the system works well on real-time data acquisition and online fault pre-warning. The statistics saved contributes to the research of vibration performance and malfunction analysis of a rolling mill. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Screw-down device, Real-time signal process, Virtual instrument, Web server, Online fault pre-warning.

1. Introduction

In modern steel enterprises, the HAGC (Hydraulic Automatic Gauge Control) system has been more and more widely used. The servo hydraulic cylinder and the screw-down device are pivotal actuator elements that play a significant role in the roll gap control. However, a continuous-rolling mill exposes different degree of serious vibration when rolling thin steel strips. The vibration phenomenon not only affects the surface quality of

the strip, but also threatens the production safety, even leads to some serious faults, e.g., strip breakage, steel stack and components damage [1-3].

Therefore, how to monitor the abnormal vibration and realize the online real-time fault pre-warning are in urgent need. A. E. Sushko et al. from Russia introduced an advanced low-waste systems for monitoring and diagnosing rolling mills and precluded the use of traditional approaches in vibrational diagnostics [4]. Kouros Mousavi Takami, et al. in Malardalen University, applied

principal component analysis to analyze and interpret multidimensional data from a cold rolling process, which focused on distinguishing between desirable and undesirable process conditions by swarm analysis and relating observations [5]. M. R. Niroomand et al. presented a set of guidelines to optimal control and prevention of chatter in rolling mills based on experimental results of the third octave chatter in a two-stand tandem rolling mill, who placed emphasis mainly on vibration analysis [6]. According to above research methods, a conventional online diagnosis system fault conditions could only supervise the amplitude of relevant factors such as temperature, pressure, vibration of a rolling mill screw-down device and output voltage of a servo-valve. Nonetheless, few studies concerned online fault pre-warning and troubleshooting strategies depending on real-time signal process.

In this paper, it is aimed to accomplish instantaneous fault diagnosis that uses a fusion algorithm of multivariate data, relying on a parallel

distributed capture technology and a visual LabVIEW programming environment. The sensors, whose output interfaces are connected to an extra high-speed data acquisition board inserted inside an IPC (Industrial Personal Computer), should be settled in the correct position in order to gather the accurate parameters information. Fig. 1 reveals the procedure of online fault identification. The characteristics of a fault are identified from the multivariate data saved in each database respectively, including the kinetic, hydrodynamic and electrical parameters of a screw-down device, and restored in local file systems ultimately.

Via a GUI (Graphic User Interface) designed by LabVIEW 2012, the system specifies and visualizes the concrete fault state. Furthermore, LabVIEW 2012 is used both for data acquisition and as a web server [7]. In other words, the GUI and database, published over the Internet, can be obtained by any entitled user who use a personal computer connected to the Internet.

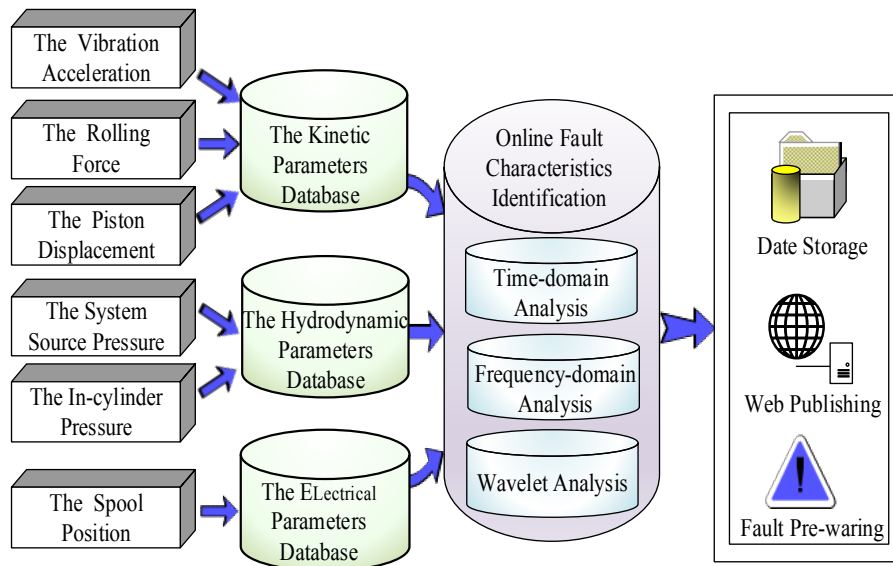


Fig. 1. The procedure of online fault identification.

2. Hardware System Description

2.1. Description of a Single Node

A main execution unit of a rolling mill can be simplified to a simple model presented in Fig. 2, which includes a rolling mill stand, a hydraulic cylinder, working rolls and supporting rolls [8]. For the reason that a traditional HAGC system has been commonly exploited in rolling technologies and the system pattern has already been fixed relatively, we just add some necessary instruments into a traditional pattern of a HAGC system, not change the ordinary system structure entirely, in order to improve system compatibility.

As a consequence, a single measurement node designed in this paper can be divided into two parts, a customary HAGC system and a few new segments we append (Fig. 2).

The customary HAGC system is mainly composed of a hydraulic power unit, a displacement sensor, a force transducer, a thickness gauge, an ADC & DAC (analog-to-digital conversion and digital-to-analog conversion) module and a servo-valve.

How the HAGC system works is briefly presented in Fig. 2. The hydraulic power unit supplies source pressure for the whole system. The sensors mentioned above are settled to measure parameters containing the piston displacement, the rolling force and the steel thickness, then transmit signals to the

central controller via an ADC & DAC module. The controller process the data and transfers control messages to a servo-valve, which provide

corresponding pressure to drive a hydraulic cylinder piston to move.

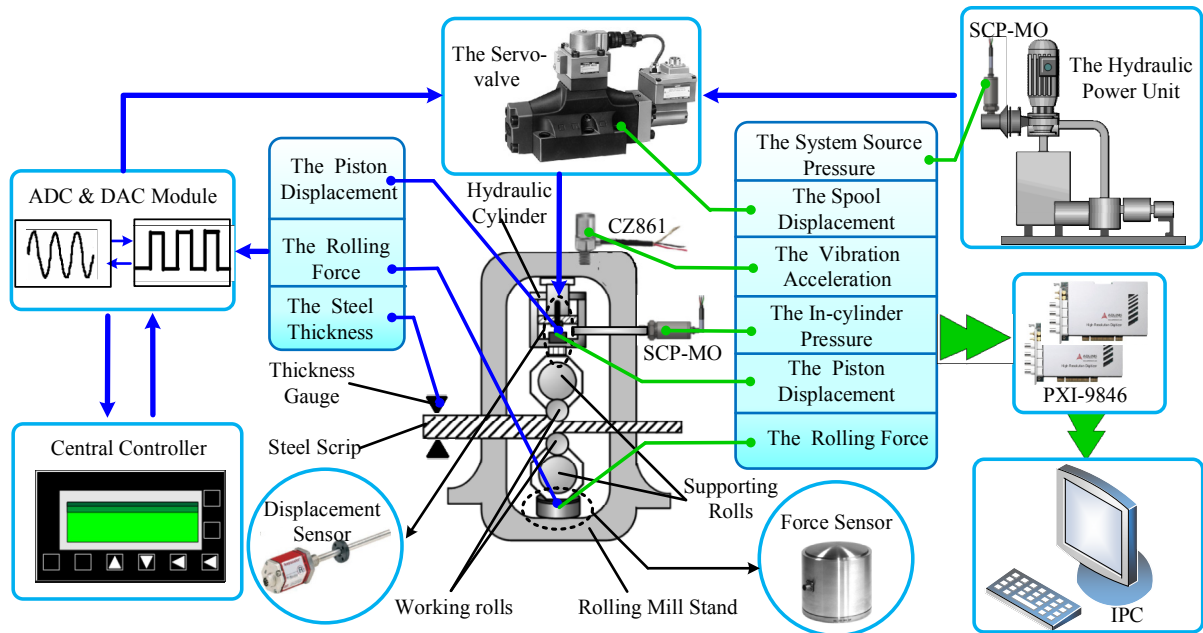


Fig. 2. The structure diagram of a single node.

To estimate the fault condition more comprehensively and precisely, appended devices are embraced into our monitoring system. Two SCP-MO series sensors are used to measure the source pressure and the in-cylinder pressure correspondingly. An accelerometer, CZ861, is fixed on the surface of a rolling mill stand to estimate the vibration states. A 40 MS/s sampling 16-bit 4-channel digitizers, PXI-9846, designed for digitizing high frequency and wide dynamic range signals, is utilized to guarantee the speed and accuracy of Data Acquisition (DAQ). The IPC consists of an 18-slot PXI Express chassis, PXES-2780, with up to 8 GB/s system bandwidth and up to 4 GB/s peripheral bandwidth for dedicated slots, and a controller, PXIe-3975, with a Intel® Core™ i5-520E 2.4 GHz dual-core processor. The hardware features of IPC are configured specially for the high-speed and parallel processing of multivariate data.

2.2. The Whole Structure of the System

A continuous-rolling mill may have four or more mill stands, which should be all monitored. Fig. 3, taking a rolling mill with five mill stands as an example, demonstrates a system architecture to establish a remotely accessible monitoring environment. The state properties of five stands (F1~F5) are recognized by variety of sensors, and stored in the local database files.

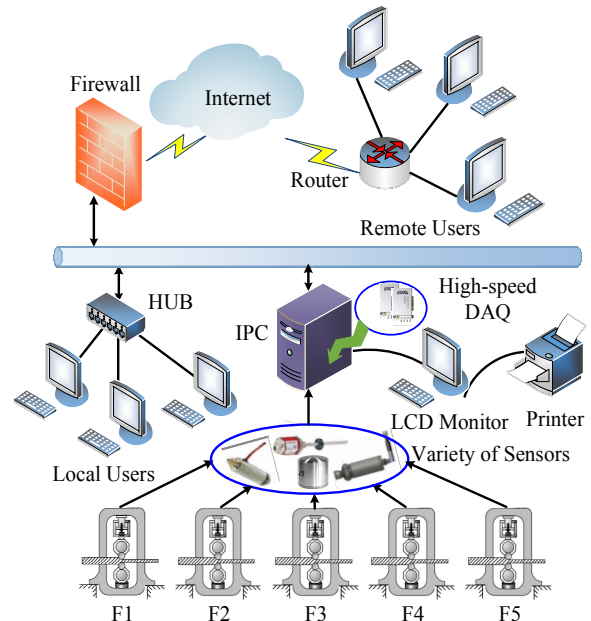


Fig. 3. The whole structure of the system.

The system is formed to support online data analysis accomplished by IPC, real-time display of fault conditions via a LCD monitor, and reports printing on users' requests.

In addition, other local users who are permitted have access to documents in host IPC. Moreover, the architecture provides compatible interface bus with

Ethernet in order that all data can be published over the Internet based on the web server [9, 10]. Remote users far away from the industrial fields can enter the monitoring system and download data as long as they have a personal computer with an IE (Internet Explorer) installed in. To increase system security and avoid network attacks, a hardware firewall is added into our network architecture to separate LAN (Local Area Network) from WAN (Wide Area Network).

3. Software Description

LabVIEW is applied in our software design. In terms of the advantages [11], Laboratory Virtual Instrument Engineering Workbench (LabVIEW™) is a powerful and flexible instrumentation and analysis software application tool which was developed in 1986 by the National Instruments. LabVIEW™ has become a vital tool in today's emerging technologies and widely adopted throughout academia, industry, and government laboratories as the standard for data

acquisition, instruments control and analysis software. For an integrated monitoring system, a compact software architecture and a friendly accessible graphic user interface is essential. The GUI of our system is constructed of a user management module and a web-based monitoring page.

3.1. Description of Software Structure

The software system, which consists of five function blocks, i.e. system initialization, data acquisition, signal process, data storage, and fault pre-warning, is designed by LabVIEW 2012 of National Instruments [12]. Every block is aimed to have its unique functionality, independent interfaces and private data. They only share public variables with each other when they are called. This category of software organization facilitates the program safety and execution efficiency. Each of function blocks will be executed on users' requests when the program is running. The software structure is illustrated in Fig. 4.

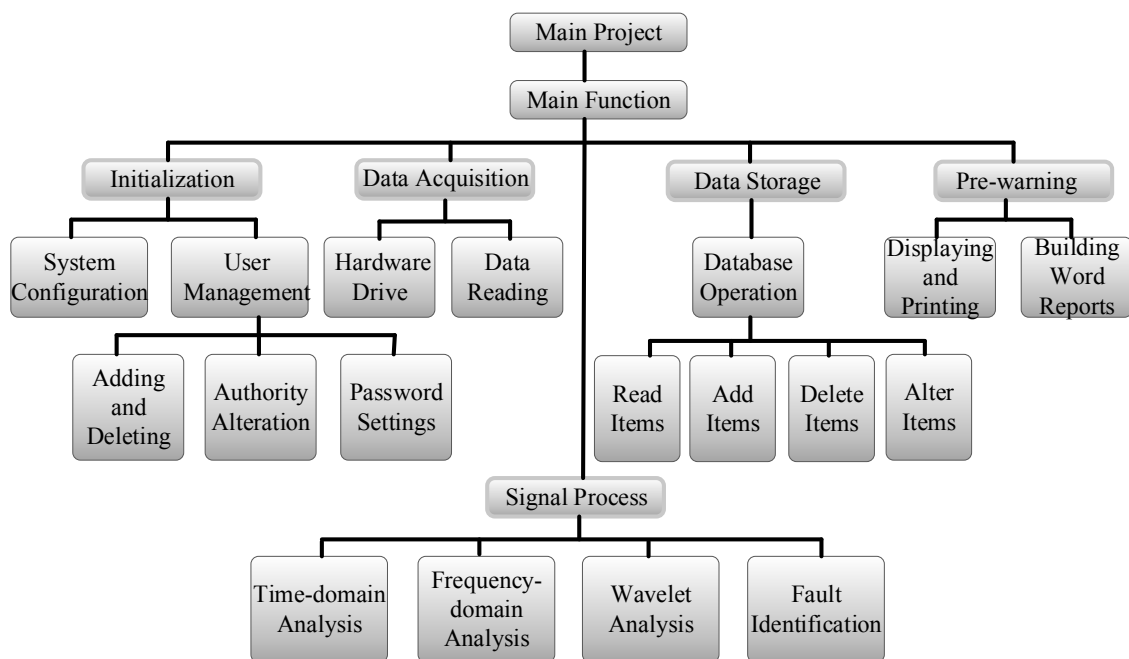


Fig. 4. The software structure.

The overall design features humanization and multifunction. The user management block provides a system administrator with rights of determining which and how many users have access to the locked system, avoiding misoperation from anyone who is not authorized. Signal Process block focuses on auto data analysis and provides respective window to show process results. Database operation block is also contained, which offers users, who are not acquainted with SQL (Structured Query Language), a friendly platform to read or edit items. Especially, a customized fusion algorithm of multivariate data is

integrated into the fault identification block with the purpose of extensive trouble diagnosis. Besides, the pre-warning block is developed not only to display the fault state but also to create a word report document that can be printed.

3.2. User Management Module

The user login panel is expressed in Fig. 5. It is presented when someone starts the system. With right user ID and 6-digit password, a user can enter the

operation interface, and his or her authentication information including user authority, login times and last time to login, will be displayed and recorded simultaneously when entering system. The authority of a user is either “Administrator” or “Test Engineer”. A user with different authority will activate different operation interfaces which are distinguished between Fig. 6 (a) and Fig. 6 (b). In details, a “Test Engineer” can only change his or her own password while an “Administrator” has the privilege to enter the user management interface (seen in Fig.7) and add, delete or edit users’ information according to operation tips.

ID	Password	Authority	Last Time to Login	Login Times
Angus	123558	Administrator	2013-10-19 11:45:49	3
Jobby	723264	Administrator	2013-10-19 16:45:47	45
John	723254	Administrator	2013-10-25 16:21:55	2
Engineer 7	654745	Test Engineer	2013-10-11 15:23:36	44
Engineer 6	852451	Test Engineer	2013-10-12 09:23:22	23
Engineer 5	784485	Test Engineer	2013-09-21 15:26:42	6
Engineer 4	845154	Test Engineer	2013-10-11 13:23:52	15
Engineer 3	845259	Test Engineer	2013-10-20 16:13:26	23
Engineer 2	205471	Test Engineer	2013-10-15 16:29:22	4
Engineer 1	123511	Test Engineer	2013-10-29 16:30:45	32
Admin	125915	Administrator	2013-10-30 08:30:27	25

Fig. 7. The user management interface.



Fig. 5. The user login panel.



(a)



(b)

Fig.6. (a)The Operation Interface of an “Administrator”, (b)The Operation Interface of a “Test Engineer”.

3.3. Web-based Monitoring Interface

A web-based monitoring interface provides convenience for remote users and extends the usability of local data. In terms of web publishing, A. P. Jagadeesh Chandra et al. have reported in [13] that, the LabVIEW programs are called Virtual Instruments, are developed and converted to HTML (Hyper Text Markup Language) page and are stored in the root directory of the server. The HTTP protocol is ideal for publishing on the web and the VI can be included in an HTML file, which can be created either manually or using LabVIEW web publishing tool and is stored in the root directory of the server. The user may access any of the HTML pages saved at root directory of web server by nearly every browser.

To increase the security of published VI, LabVIEW offers the Browser Access section on the web server page of the options dialog box that can be used to configure which browser addresses can view the VI front panels. A browser access List can be created to allow and deny access to individual browser addresses. You can also use the web server: TCP/IP access list property to allow and deny access to browser addresses programmatically [14]. For running the application, a copy of the LabVIEW environment or LabVIEW run-time-engine has to be installed, it can be built as an executable program or be published as a remote panel operated through the Internet. The cross-platform characteristics of the graphical development system enable it to be run on different host operating systems or in virtualized environments [15].

Fig. 8 presents the web page of GUI developed for our system. Two gauges and four meters are put to display the parameters value gathered from the rolling mill, and the real-time curve which reflects how the parameters change over time. Embedded in the waveform chart, a menu ring named “Parameter Selecting”, is used to choose which curve a user intends to watch. Besides, a few of push buttons for specific subroutine and round LEDs for indicating fault conditions, are contained into the monitoring panel. Synchronization of the VI front panel and browser is then maintained as follows. When a user with a right IP address points a browser to the web page replica of the VI, a connection is automatically

established between the remote PC and target host. Once connected, the client will access to the same login panel as the local host. Then, by giving right user name and password, the remote access can be authorized, and the client can enter the same

monitoring interface that a local user visits [16]. As a remote client, you can request a right to control the VI by right-click on the monitoring panel. Once permitted, a remote user can implement all functionality as a host runs.



Fig. 8. The web page of GUI.

4. Conclusions

The results obtained in the course of this experiment clearly demonstrate that our system performed well on fault pre-warning. Variable parameters, picked up by a series of sensors which are settled in carefully selected locations, are characteristic of the comprehensive fault condition. The high-speed data acquisition board and IPC processor facilitate parallel processing of multivariate data. The software system designed by LabVIEW provides an appropriate fusion algorithm to analyze multivariate data and extract fault features. The VI can be integrated to an executable file with a LabVIEW run-time-engine, which can run in any common personal computer even with no a complete LabVIEW environment installed in. This enhances the software compatibility. A web-accessible GUI designed in this paper makes it available for a remote user to watch running condition of a rolling mill in real time.

Even though, it is a pity that some jamming signals exit and impact accuracy of fault diagnosis occasionally on account of complicated situation

where sensors are located, further research aiming at specific interference suppression and strategy of improving electromagnetic compatibility is carrying on and has progressed much at present. It is proved that this proposed scheme is a good alternative to real-time fault pre-warning system. The virtual instrumentation case we have finished has the potential to operate as a model framework of online monitoring technique which can be used in other industrial domains.

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References

- [1]. Yan Xiaoqiang, Machinery-electric-hydraulic coupling vibration control of hot continuous rolling

- mills, *Journal of Mechanical Engineering*, Vol. 47, Issue 17, 2011, pp. 61-65.
- [2]. Wang Yongtao, Zang Yong, Wu Diping, Fan Xiaobin, Studies on the cause of vibration of CSP rolling mill, *Journal of Vibration, Measurement and Diagnosis*, Vol. 28, Issue 4, 2008, pp. 395-399.
- [3]. Yan Xiao-Qiang, Bao Miao, Li Yong-Kui, et al, Research on the vibration of FTSR hot rolling mill, *Engineering Mechanics*, Vol. 29, Issue 2, 2012, pp. 230-234.
- [4]. A. E. Sushko, Methodology of introducing hardware/software systems for monitoring and diagnosing rolling mills, *Metallurgist*, Vol. 54, Issue 5-6, 2010, pp. 367-373.
- [5]. Kourosh Mousavi Takami, Jafar Mahmoudi, et al, Multivariable data analysis of a cold rolling control system to minimise defects, *International Journal of Advanced Manufacturing Technology*, Vol. 54, Issue 5-8, 2011, pp. 553-565.
- [6]. Mohammad Reza Niroomand, Mohammad Reza Forouzan, Mahmoud Salimi, et al, Frequency analysis of chatter vibrations in tandem rolling mills, *Journal of Vibroengineering*, Vol. 14, Issue 2, 2012, pp. 852-865.
- [7]. Maria T. Restivo, Joaquim Mendes, António M. Lopes, et al, A remote laboratory in engineering measurement, *IEEE Transactions on Industrial Electronics*, Vol. 56, Issue 12, 2009, pp. 4836-4843.
- [8]. Dong Yuxiang, CAT system research of strip rolling mill electro-hydraulic servo performance based on virtual instrument technology, *Computer Measurement & Control*, Vol. 18, Issue 9, 2010, pp. 2076-2079.
- [9]. K. Venkata Lakshmi Narayana, A. Bhujanga Rao, Design and development of a pressure transmitter using modified inductance measuring network and bellow sensor, *Sensors & Transducers*, Vol. 150, Issue 3, March 2013, pp. 32-39.
- [10]. K. A. Abhfeeth, D. Ezhilarasi, Monitoring and control of agriculture parameters in a greenhouse through internet, *Sensors & Transducers*, Vol. 150, Issue 3, March 2013, pp. 106-111.
- [11]. Mohamed Zahran, Yousry Atia, Abdullah Alhosseen, Wired and wireless remote control of PV system, *WSEAS Transactions on Systems and Control*, Vol. 5, Issue 8, 2010, pp. 656-666.
- [12]. André Guimarães Oliveira, Alexandre Balbinot, Virtual instrumentation with application in multiaxial extensometric force platform, *Sensors & Transducers*, Vol. 138, Issue 3, March 2012, pp. 35-49.
- [13]. A. P. Jagadeesh Chandra, R. D. Sudhaker Samuel, Web-based collaborative learning architecture for remote experiment on control of bioreactor's environment, *Journal of Software*, Vol. 4, Issue 2, 2009, pp.116-123.
- [14]. LabVIEW 2013 Help (<http://zone.ni.com/reference/en-XX/help/371361K-01/vhowto/allowingdenyingwebbrowser/>).
- [15]. Grigore Stamatescu, Valentin Sgârciu, Integration of wireless sensor networks with virtual instrumentation in a residential environment, *UPB Scientific Bulletin, Series C: Electrical Engineering*, Vol. 75, Issue 2, 2013, pp. 41-52.
- [16]. Amine Yazidi, Humberto Henao, Gérard-André Capolino, et al, A web-based remote laboratory for monitoring and diagnosis of ac electrical machines, *IEEE Transactions on Industrial Electronics*, Vol. 58, Issue 10, 2011, pp. 4950-4959.


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