Geodetic Control and Setting Measurements in Mechanical Metrology

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SUMMARY

The measuring technologies of engineering surveying have proved over the past decades, they can successfully be applied in several fields of engineering specialities. By now, we may say, the geodetic measurements in industrial metrology have been not only a newer application area but a separate sub-field of engineering surveying. The new metrological problems always require new solutions. Despite the rapidly developing instrumentation in the surveying, there are some problems to be solved using classical measuring methods. There are certain circumstances when laser scanners, digital levels and laser distance meters cannot be used, or, the accuracy of them is not sufficient. This can also be said about some mechanical metrological methods. In our paper, we present some special solutions to solve mechanical metrological tasks which have crucial importance in product process. The manufacturer, where these problems arose years ago, is the ALCOA Köfém, Hungary. It is one of the largest half-ready aluminium manufacturers in Central Europe, where aluminium moulds, rolled plates, simple and complex aluminium shapes are manufactured by huge press machines. The product process is rigorously standardised and the products have to satisfy high quality requirements. The quality highly depends on how the press machines operate in the production. They are very complex structures and in need of regular maintenance and repair.

In 2004, we attempted to give an overview about these measurements during the INGEO Conference, Bratislava, but at that time, we had not had permit yet from the manufacturer to give full paper on the solutions. The publication would have required more visualisations by three dimensional models and photos, as well as the detailed presentation of the measured structures and their functions, but since, we have got the necessary authorisation. That is why we decided, we were going to return to this topic again and share our experiences with those surveyor colleagues who might be interested in such solutions during their works that we have employed. We hope, we can contribute and add something to their activity by our study.

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1. THE GENERAL STRUCTURE OF PRESS MACHINES

Before discussing the control and setting measurements, for the sake of better understanding, it is worth to have couple of words on the main structures and their functions of press machine (Fig. 1). The raw aluminium blocks are fed perpendicularly to the longitudinal axis that coincides with press axis, or in other words, the so-called alignment. After feeding, the main cylinder ram (1) pushes the aluminium into the container (2) and they move together towards the die exchange cassette (3). The container is heated around 360 degrees thereby melting the aluminium. The melted material is formed by the die exchange cassette when it passes through. Finally, the formed aluminium quits the press machine at the front-plate (4) and cooled down by ventilators (5). The conveyor (6) rolls the half-ready product before it is cut or rolled around special cylinders.

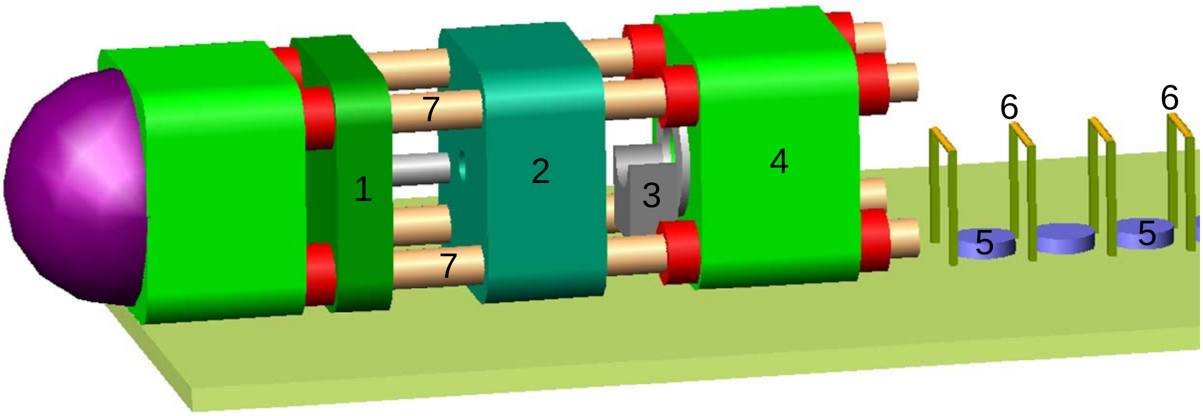

Fig. 1. The main units of press machine

The above written process determines those geometrical conditions that must be fulfilled by the units of press machine. The axis of main cylinder ram and container has to coincide with each other together with the die exchange cassette's one. Since the coming-out and formed aluminium can be cooled gradually and not at once, therefore the product deforms if the rollers of conveyor are not levelled within ± 0.5 mm. This additional condition is also controlled by levelling. Deformations can be caused by divergent tie rods (7), because they lead both the main cylinder ram and the container. If the tie rods are not parallel spatially to each other then they must be adjusted. To this adjustment, also geodetic control measurements serve as a basis.

Despite the seeming simplicity of the conditions to be fulfilled, the huge mass of press units causes the greatest matter. The units are tens of tons and moveable with difficulties. The tolerance of deviation of coaxial axes from each other is ± 0.2 mm. This rigorous requirement demands good cooperation between the press machine operator, the leading mechanical engineer and the surveyor. Their individual task must be carried out with big care but not independently from each other.

2. THE CONTROL AND SETTING MEASUREMENTS

The control and setting measurements are based on that setting out network which was established during the installation of press (Fig. 2). Numbers of control and axis points are marked but only two of them can be used for horizontal settings; they mark the principal axis of press machine.

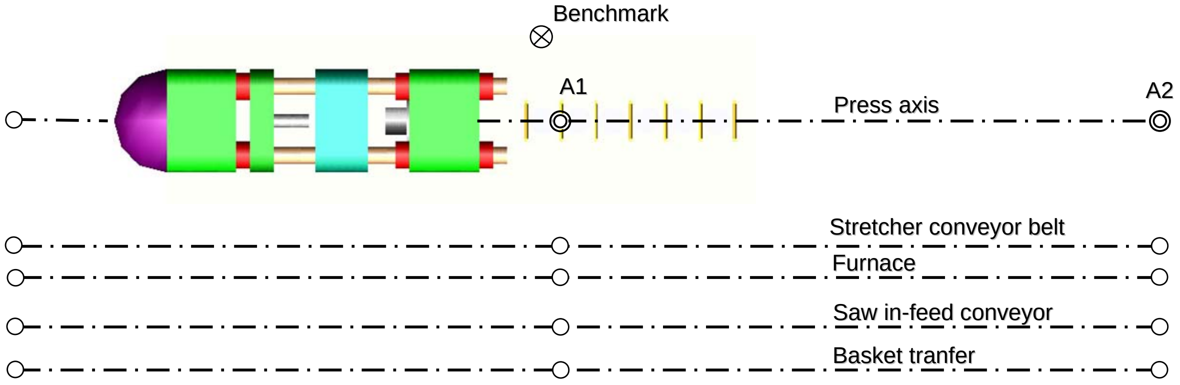

Fig. 2. The setting out network

Fig. 3. After setting out and full installation
- by courtesy of ALCOA KÖFÉM

The marked points are sunk into the floor being in a steel box and saved by a rustproof spiral cap. The centre of mark is a punched or drilled hole with the diameter of 0.5 mm.
The measuring process comprises two main steps (Fig. 4). First, the actual height DH of ram axis is determined at its starting position with respect to a benchmark (1) located within few metres from the station (2). Because of being obstacles in sight, only optical level can be used. To eliminate the systematic error due to the unequal instrument-rod distance, we employ Zeiss NI 002A precise level with that we can measure in two compensator positions. The height difference between the ram axis and benchmark is measured twice. The difference must not exceed 0.1 mm else the readings are carried out again.

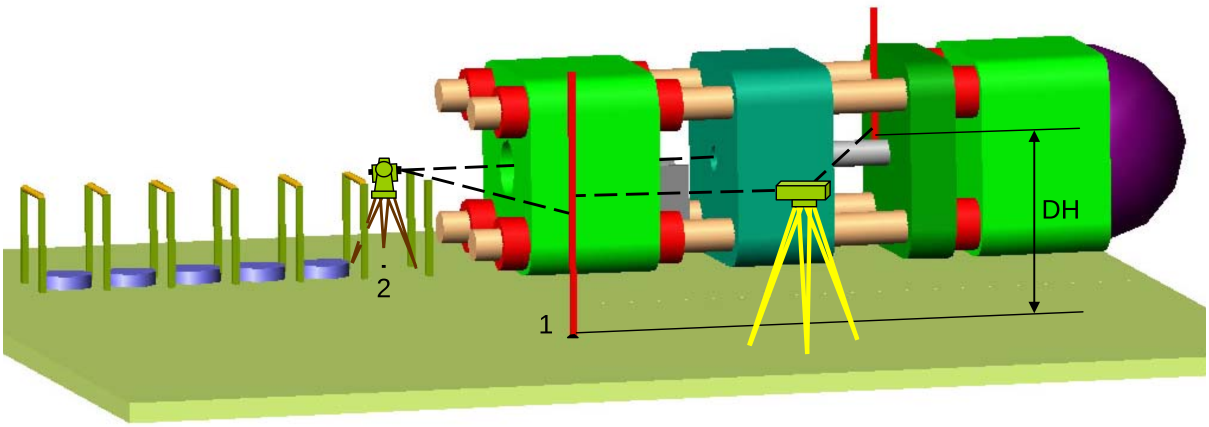

Fig. 4. The measuring process and alignment

The starting point of ram marks the press axis vertically; therefore further units have to be adjusted to it. To transfer this height onto the path of motion, furthermore onto the container and die exchange cassette, we set a total station front of the front-plate over the marked axis point (2). The height transfer is carried out trigonometrically. However, the total station must be set vertically coinciding with the ram axis within ± 5 mm. The reason of this is, we need to see through the container that carries an inner tube having a diameter of 5…10 mm. Both the front and the back of the tube are measured in order to detect tilting motion of the container. Without consideration of this fact, the setting measurements cannot be carried out.
Formerly, THEO 010 A optical theodolite was used for horizontal settings because the forced centring allows the interchangeable use of THEO 010A and Zeiss NI 002A. However, this technology has been replaced by now. Classically, the horizontal and vertical controls and settings were carried out separately, but with total station, we can do them simultaneously. The prerequisite of employing total station is the distance measurement onto the front of the particular unit to be set. This can be done onto tapes mounted on the units or the moving auxiliary devices.

In the case of die exchange cassette, this can be achieved without difficulties. An aluminium plug is placed inside the cassette, and a tape is mounted above it. The centre of the plug is punched marking the centre of cassette too. In the case of the setting of ram, this aluminium plug is placed inside the ram’s tube and targeted similarly to the cassette.

The setting of container, however, is more complex. It has to be measured at its front and back. To this, a tube is placed inside the container that carries very thin cross hairs (Fig. 5). The distance is measured only onto the front. Additionally, during the reconnaissance, the length of tube is also determined.

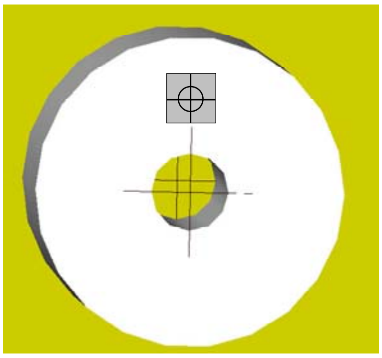

Fig. 5. Cross hairs and tape to the measurement of the container

Because of the peculiarity of press machine's operation and its structure, the setting measurements cannot be carried out simultaneously for all units. First, we measure and set the die exchange cassette, then the ram and the container comes next. Finally, the die exchange cassette is controlled again, because it can displace during the long time of total setting. Since the mass of the different units can reach lots of tons, therefore the vertical and horizontal settings have effect on each other. Couple of tenth millimetres of horizontal displacement can result several tenth millimetre displacements vertically, and vice versa. Usually three, but sometimes four different horizontal positions are necessary measuring the ram and container along their motions.

Since the settings require complex calculations, therefore we developed a simple program to carry out this task effectively. The input data beyond some additional information are the height of axis to be set, the reading of the graduation on the staff, the zenith angles and the horizontal distances. In the property of these data, the program computes the instrument height and the position of the marked points. The results of calculations are saved in a file that can be viewed and handed over to mechanics for appropriate documentation immediately.

3. CONTROL MEASUREMENTS DUE TO IMPERFECT OPERATION OF PRESS MACHINE

The control and setting measurements last usually 10…12 hours, including, of course, the work of mechanics. But longer duration has also occurred. The longest setting lasted four days all in all. It may happen, the settings do not result success due to mechanical and electronic problems. Since the latter is not our concern, therefore we just focus on those mechanical errors that can be detected by geodetic control measurements. These are the diversion of tie rods and the deformation and tilt of pressure ring.

3.1 The Control of Tie Rods

The tie rods hold firmly the whole structure (Fig. 6). There are four tie rods (1) stressed by the tie rod nuts (2). The tie rods are responsible for the even motion of the ram and container. If the tie rods are not parallel to each other, then the ram and container tilt and lurch during their path making the settings impossible. According to the mechanics' statement, this anomaly mainly attributes to the unequal distance between the fronts of nuts. To cease the misalignment, the distances between the fronts have to be adjusted within ± 0.3 … 0.4 mm. The sought distances, however, cannot be measured directly. On the one hand, measuring tapes and laser distance meters do not suit the expected accuracy. On the other hand, in the case of some press machines, there are obstacles between the fronts, therefore we have to determine the range indirectly by direction measurements.

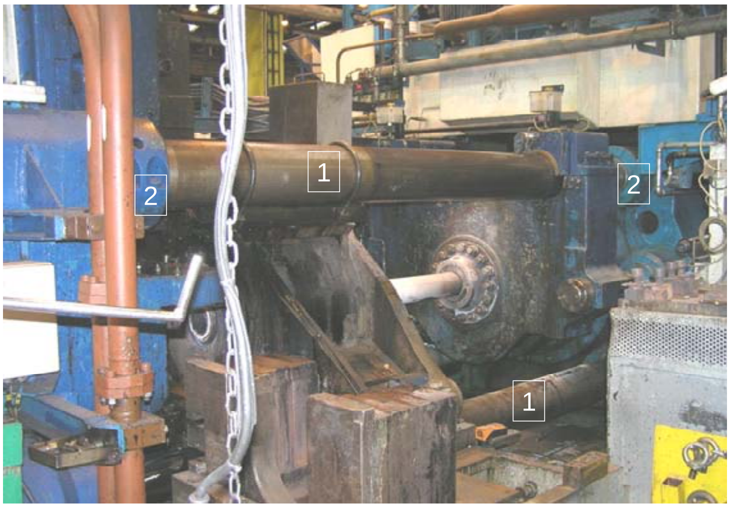

Fig. 6. The tie rods (1) and the nuts (2) - by courtesy of ALCOA KÖFÉM

To determine the diversion of tie nods, two axis points serve as a basis to develop a micro network around the press (Fig. 7). Because of the lack of space, only two furthermore points can be set out. To decrease the influence of the errors of distance measurements on the sought quantities, the new network points are set out approximately in the extension of the direction of nuts' front.

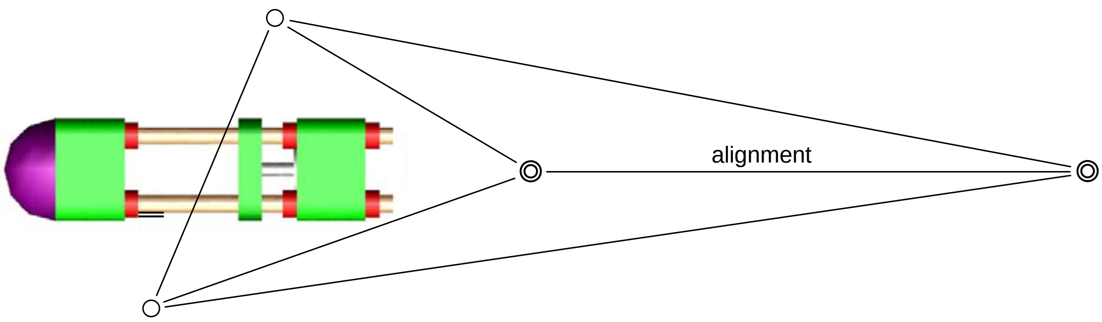

Fig.7. The micro network for determining the diversion of tie rods

Unfortunately, intersection cannot be employed due to different structures which obstruct the observations, therefore we mount a magnetic calliper on the front of nuts (Fig. 8).

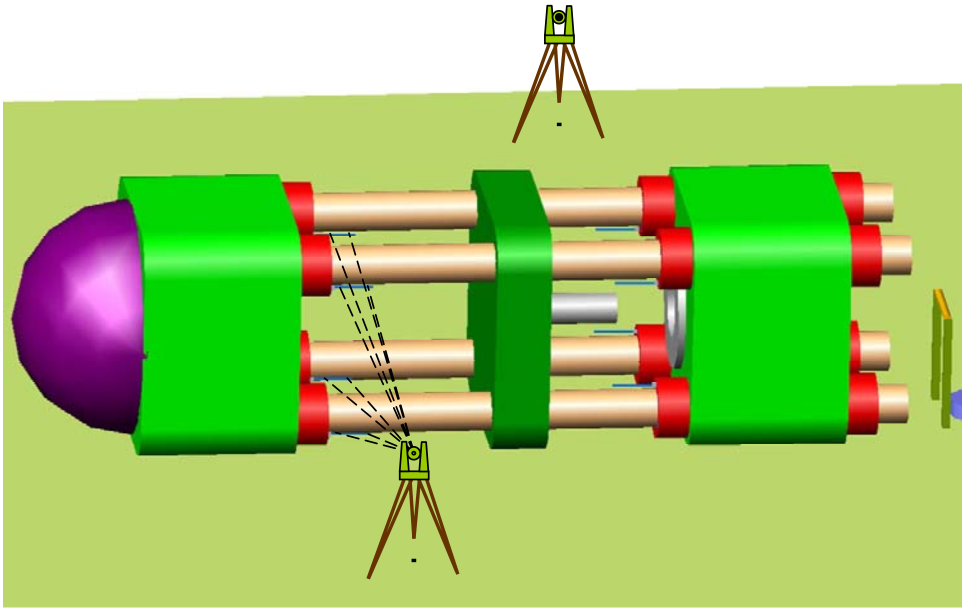

Fig. 8. The measurement of tie rod nuts

The calliper is measured at two different graduations recording the direction, horizontal distance and the graduation value itself. To assure redundant observations, the auxiliary points on the calliper are measured twice. The network is adjusted as a free network and the datum is chosen so that the y or x axis of coordinate system made parallel to the press axis. According to our experiences, relative error of 1/70000 can be achieved by forced centring observations. Employing this technology, the distances between tie rod nuts can be determined with the accuracy of 0.2 mm, despite, the accuracy of total station is not better than 1 mm.

3.2 The Control of Pressure Ring

The function of pressure ring is to convey the pressure of container to the front-plate during the extrusion and distributes the forces evenly on the die exchange cassette, which, as we have written, forms the melted aluminium. Since the container collides with the pressure ring, therefore it wears and deforms continuously. Deformations over 0.1 mm may be significant, therefore quasi-direct measurement has to be employed to prevent the propagation of undesirable errors. To achieve this, measuring to straight line seems as an obvious solution by that we can eliminate systematic errors as well.

The baseline is set out based on the plate of the so-called cross lattices (Fig. 9). In principle, the plane of the lattices (1) and pressure ring (2) has to be parallel to each other. Setting up a total station in the extension of front of lattices, direction and distances are measured and readings taken on the calliper fixed to the lattices. Based on these quantities, a parallel vertical plane to the cross lattices can be calculated and set out. Then the calliper is aligned along the perimeter of pressure ring at which readings are taken. Usually eight points are measured in turn.

The spatial alignment and deformations of pressure ring can be modelled in a spatial coordinate system and the parameters of a plane are calculated by adjustment. The alignment parameters, i.e. tilting angles and deformations serve as a basis to grind the ring adjusting its deformed surface.

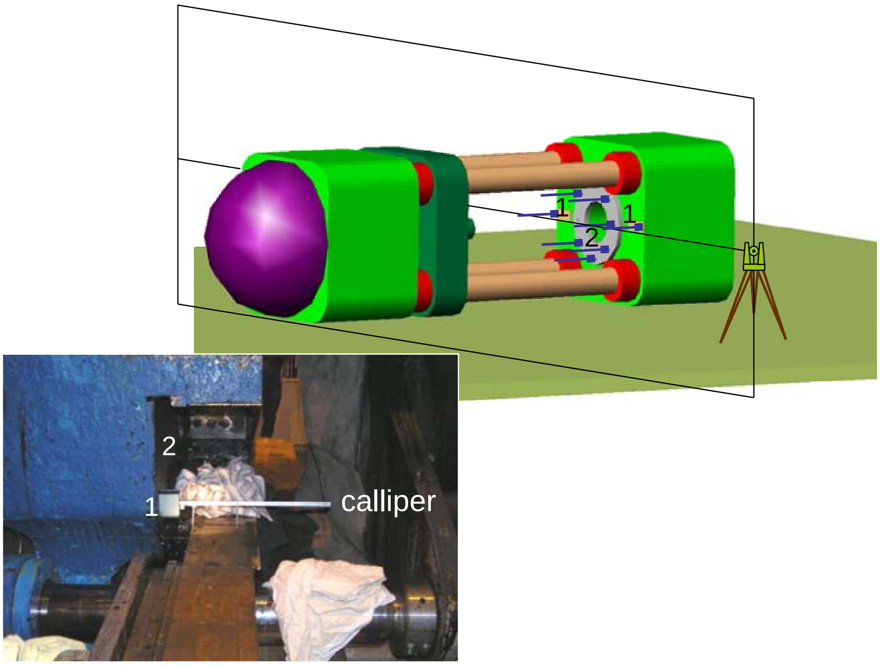

Fig. 9. The control of pressure ring - by courtesy of ALCOA KÖFÉM

4. THE ACCURACY OF CONTROL AND SETTING MEASUREMENTS

Without entering into details and referring to our earlier study (Ágfalvi, Gyenes, 2004) we just touch on the most important factors that bias the accuracy of measurements. Simple derivations and formulas can also be found in the above mentioned paper.
The spatial position of the axis of ram, container and die exchange cassette can be determined with the accuracy of ± 0.1 … 0.2 mm in the case of non-preheated press. If the press is pre-heated, then the circumstances become unfavourable and the refraction deteriorates the accuracy that reaches ± 0.5 mm in this case. For these reasons, cold press is advisable to carry out the settings.

As we have mentioned in section 3.1, the range of tie rod nuts can be determined within ± 0.2 mm with the appropriate choice of stations. It has to be noted, the less the number of stations, the higher accuracy can be achieved. To keep this condition favourably is sometimes extremely difficult if there are obstacles in sight.

The deformations of pressure ring can be detected with the accuracy of ± 0.1 mm. Moreover, the measuring technology presented in section 3.2 has more advantages. First, there is need only for one station; thereby the eccentricity errors do not appear as we should reckon on employing intersection. Second, the accuracy of setting out of vertical reference plane does not play key role in the relative positioning of measured points on the ring, because, depending on type of press, the diameter of ring does not exceed 60 … 70 cm. Also, the remaining tilting errors of compensator can be eliminated in the differences of readings because they are taken in same plane. Control measurements of ground rings have also proved the accuracy of ± 0.1 mm. They have been re-measured independently after grinding and the differences did not exceed 0.1 mm in absolute value. This control also confirms the estimated accuracy and the results are in harmony with theoretical aspects as well.

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BIOGRAPHICAL NOTES

Mihály Ágfalvi currently works as a Professor at the Department of Geodesy at the Faculty of Geoinformatics, University of West Hungary. He graduated as a land surveyor engineer at the Technical University of Budapest in 1967. He worked at the Company of Surveying in Budapest from 1967 until 1970. In 1970 he was appointed as an assistant at the Department of Geodesy of the College of Surveying and Land management in Székesfehérvár. He obtained his Dr.techn. academic title at the Technical University of Budapest, 1979. He took actively part in the work of Hungarian National Committee (HNC) of FIG and was the president of HNC from 1998 to 2002. He is also the member of the executive committee of Hungarian Association of Geodesy Cartography and Remote Sensing. His teaching and research work are focused on Engineering Geodesy.

Róbert Gyenes has been working as an associated professor at the Faculty of Geoinformatics, University of West Hungary since 1997. He graduated as a land surveyor (B.Sc.) from this college in 1996. After his studies, he worked for a year at a cadastral surveying firm and returned to the scene of his earlier studies. In 2005, he graduated as a Geomatics M.Sc. engineer from University of Applied Sciences, Karlsruhe. His research field covers the different data processing method of surveying measurements, adjustment computations and software development.

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