# Extrusion Press Alignment with Modern Technology

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**ABSTRACT** --- The Industrial Measurement Center supplies dimensional measurement and analysis services to industry and has experience in providing dimensional measurement for extrusion press alignment and adjustment in the aluminum industry. A brief overview of condition monitoring and maintenance management techniques and the relationship with dimensional aspects is given to provide the appropriate perspective for the maintenance engineer. The methods and application of the various traditional tools for press alignment are mechanically based and are essentially discrete linear one-dimensional incremental measurements of components. Modern three-dimensional (3D) Coordinate Measurement Systems (CMS), such as optical triangulation with electronic theodolites, or optical polar ranging with laser tracker systems, provide a 3D global approach or "combined picture" of the 3D geometric relationships (position, attitude, and geometric characterization) of all press components. This paper discusses the advantages of modern technological approaches to replace or complement the traditional methods and tools of extrusion press alignment. The combined measurements for the static, moving components, and operational monitoring phases were carried out on an older extrusion press that had alignment problems. The adjustment solution applied enabled continued production at minimal cost for a press that would otherwise have been out of production for a long untenable major overhaul.

## INTRODUCTION

The Industrial Measurement Center (IMC) is an applied research unit operating from within the Department of Surveying at the University of Otago. Industrial Measurement is taught as an elective, and a formal commercial structure is provided through which specialist staff skills and resources in many areas of technology-transfer are delivered to industry. Defined objectives are creating research opportunities in this specialist field, providing benefits of real industry experience transferred to students, and generating an important revenue flow into the University. The IMC is currently the only applied research unit in this field in New Zealand and its innovative solutions have earned it a reputation as a center of research excellence.

The commercial objectives of the IMC are:

- To provide a precision measurement and analysis service to industry.
- To assist in inspection, checking, adjusting, assembling, installation and maintenance of 3D components, work pieces, entire machines or structures according to design drawings and specifications.
- To provide effective solutions using leading edge technology.
- To increase flexibility, productivity, efficiency, and quality of New Zealand industry.

Work carried by the IMC covers any industry but has mainly been in the following: aircraft, mining, smelters, aluminum, pulp and paper, machine workshops, and hydro-electricity generation. A measurement and analysis service that the IMC provides in the aluminum industry is for extrusion press alignment and adjustment.

The purpose of this paper is to present some general ideas on press establishment, periodic alignment and adjustment, and to illustrate these using a specific press alignment example with the expectation that it will be of benefit to the extrusion industry. Specifically this paper discusses the advantages of modern technology approaches to replace or complement the traditional methods and tools of extrusion press alignment. The focus is on mensuration, though reference is made to condition monitoring and maintenance management techniques to provide the appropriate perspective for the maintenance engineer.

## CONDITION MONITORING AND MAINTENANCE MANAGEMENT

*Condition monitoring* refers to observing and recording the initial or current state(s) of a machine at various speeds (including stationary), loads, and times to provide information about reference conditions and subsequently about changes in system parameters. Methods used to detect these changes include visual, vibration, noise, balance, wear debris, thermal, compliance, and geometric and dimensional monitoring. Parameter variations or comparisons may indicate symptoms of malfunction or the existence of a defect leading to system deterioration, malfunction, or failure. To keep machinery running smoothly for as long as possible or even with improved efficiency, various *maintenance management* techniques are used to determine the type, period, and frequency of inspection, servicing, and minor or major overhaul/refurbishment used. These techniques include establishment maintenance (setting up the initial state well within compliance specifications); reactive maintenance (fixing the machine when it has run to failure); preventive maintenance or on-schedule maintenance (overhauling at specified frequency regardless of operating condition); predictive maintenance (predicting servicing or overhaul requirements based on the detection of malfunction symptoms); and proactive maintenance (action taken before anything starts to fail, preventing degradation in the first instance). An important consideration is that once a defect is identified, the source, cause, and location of the problem must be diagnosed, and usually quantified before it can be remedied or mitigated.

There are a number of specialized measurements that can be made during both the condition monitoring and the diagnostic phases by maintenance engineers and specialists in each type of measurement. When the problem is suspected to be geometric or dimensional, then dimensional industrial measurement is most suitable to provide the solution for making accurate maintenance management decisions.

The geometric or dimensional aspects of an extrusion press are fundamental to proper press alignment which is required for minimizing downtime and production waste. In establishment maintenance, the press should be installed according to the original designer/manufacturer specifications, especially with respect to tolerances. If the instructions and recommended procedures are carefully studied, the ideal three-dimensional geometric relationship of the press components can be determined. Furthermore, understanding of the operational principles provides more information about the functions of the moving components for their adjustment to compliance under various operational load and event conditions of the ram, the container, and of extrusion. In very simple terms, and without referring to other important practical aspects such as foundations, the main three-dimensional geometric relationships of the static components (see Figure 1) of a simple press are that:

- The press base (bedplate) is level with respect to gravity, and the relevant contact points lie in a flat plane.
- The back (resistance) platen is fixed perpendicular and the front platen is located perpendicular to the base with both platens parallel.
- A pressure bush has its hole centered in the front platen and its front surface flat and parallel to the front platen.
- The crosshead and container guide ways are straight and parallel longitudinally to the base, and are symmetrically spaced about the press center line with the correct dimensions.
- The main cylinder, bearing bushing, flange, and ram piston are concentric and are centered on and perpendicular to the back platen.
- The crosshead is center-mounted on the ram and is itself fitted with a straight and centered extrusion stem perpendicular to the back platen.
- The press center line is the line joining the platen centers and all the platen centered components lie on this line.
- The geometric center lines of each of the four machined tie rods (columns) are parallel to and symmetrically located about the press centre line so that their mean is parallel and lies on the press center line.

It is clear that, as more components are added, a more complete three-dimensional model is built up equivalent to the original design drawings and, with the specified tolerances and critical dimensions, that this is the mathematical inspection template used during measurements for compliance of any of the press components.

Similarly, the three-dimensional geometric relationships of the moving components of the press are that:

- The ram piston and the extrusion stem move along the press center line over their full stroke.
- The center line of the container bore is coincident as it moves along the press center line

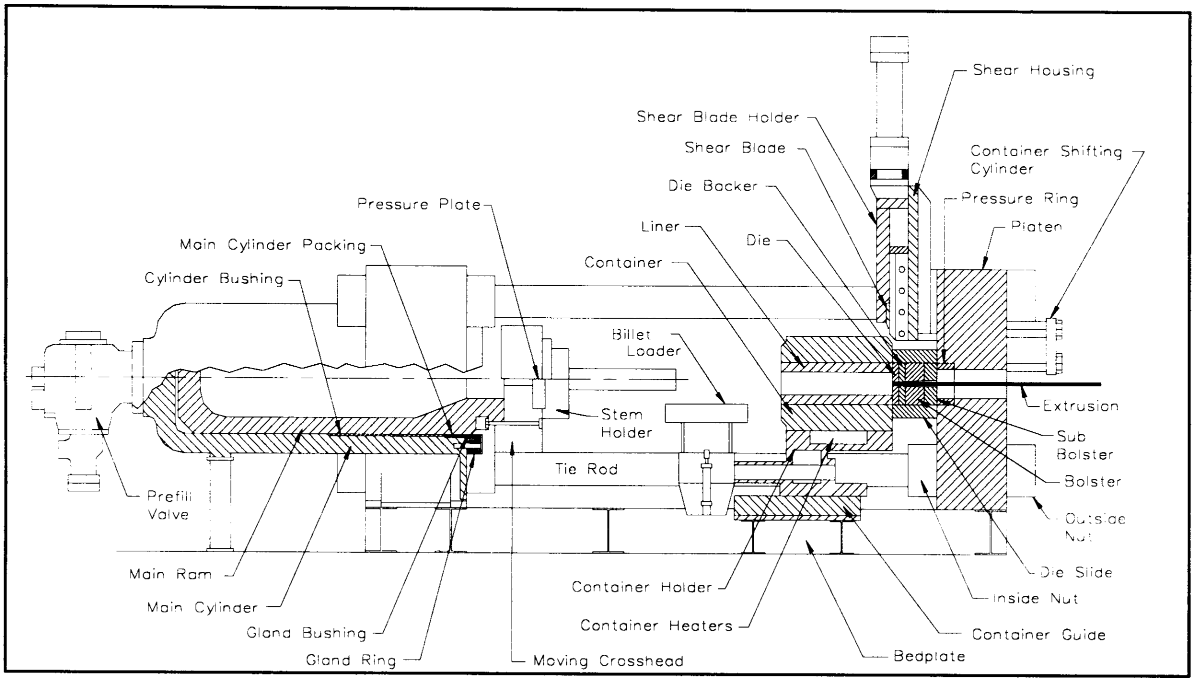


**Figure 1.** Diagram of press components (Courtesy of Kennedy 1996).

from its open to closed state, under container pressure and during various extrusion load(s).

- The center line of the tooling stack (die stack) is coincident with the press center line in its closed state, under container pressure and during various extrusion load(s).

These relationships must be correct when the press is at operational working temperature to allow for thermal growth effects. The above also implies that some sort of monitoring process of the major press components should be carried out during the various operational load and event conditions of ram and container pressure and extrusion.

Press alignment techniques and dimensional measuring instruments can be grouped broadly into traditional and modern technology.

The methods and application of the various traditional tools for press alignment are essentially linear one-dimensional (1D) incremental discrete measurements of components which together may give the full geometric condition of the machine with respect to gravity, and then give an indication of what corrective adjustments are best. More likely, each alignment sequence is heavily dependent on a previous one, thus requiring corrective action before being able to go onto the next one or before being able to suitably relate the components together to their specified geometric characterization (flatness, levelness, parallelism, squareness, symmetry, and center line linearity). A full press alignment determination with traditional techniques is very time consuming (several days) with some parts having to be measured in a dismantled state and others only able to be made with the press in a cool state. The time and uncertainty associated with the incremental buildup of the three-dimenaional geometric component relationships from one-dimensional measurements, make the traditional press alignment measurement task one that would be reluctantly (or only as a very last resort) carried out, particularly with an unscheduled outage cutting into production or even during normal scheduled maintenance. However, some simple press adjustment tasks and checks on an individual component are likely to be more practical and economical using the traditional methods.

Modern three-dimensional (3D) Coordinate Measurement Systems (CMS) provide a three-dimensional global approach or "combined picture" of the three-dimensional geometric relationships (positions, attitudes, and geometric characterization) of all press components. A full press alignment measurement is faster, more accurate and reliable, and has several other advantages over traditional methods.

## TRADITIONAL ALIGNMENT METHODS AND TOOLS

Traditional measurement equipment for press alignment consists of the standard engineering metrology tools used typically by fitters and machinists in a mechanical engineering workshop, together with some extended devices for larger dimensions, and specially designed and custom made devices for specific inspection tasks. Additionally, Optical Tooling and precision surveying instrumentation have been used in attempts to gain the benefits of the prevailing methods of the time.

*Mechanical* measurements are made by press maintenance people using micrometers, calipers, dividers, feeler gauges, digital type indicators, and precision machinist levels, straight edges, squares, and scales[2]. For larger dimensions, extended stick micrometers, piano wires, and plumb bobs are used; and specially designed and custom made devices which include angled guide way levelling adapter blocks, trammel rods, and special anchor plugs and disks for locating and tensioning alignment wires or tubes. Details on the design, application and operation of these mechanical tools for extrusion press alignment are well documented in two papers[3,4] and in Chapter Three, Inspection and Maintenance of the *Extrusion Press Maintenance Manual*[5]. These details will not be discussed further here except where they are pertinent for comparison with the modern technology approaches.

*Optical tooling* uses powerful alignment telescopes to obtain precise reference lines and reference planes from which accurate measurements are made with optical micrometers, optical tooling tapes, optical tooling scales, and micrometer measuring rods[6]. This orthogonal measuring system was developed for the aircraft industry but has now been rapidly superseded in many industries by faster modern technology. For press alignment, an alignment telescope is mounted in the egress hole of the front platen to establish an optical center line and a target on the ram stem sighted in three positions along its motion provides its alignment check and that of the main ram, (assuming the stem is straight and parallel with the ram). The telescope line of sight is set using either the bore in the die pressure pad or the intersection of cross-wires in two places made by the intersection of a taut wire criss-cross configuration over the tie rods (tie-rod referenced centering, see Figure 2). Limitations are that the bore is often badly worn and not parallel, and the tie rods center reference may be from asymmetrically spaced rods or may not be on the center line.

Precision *surveying instruments* for press alignment include surveyor's levels and transits used mainly with precision graduated scales to establish various press components level with respect to gravity.

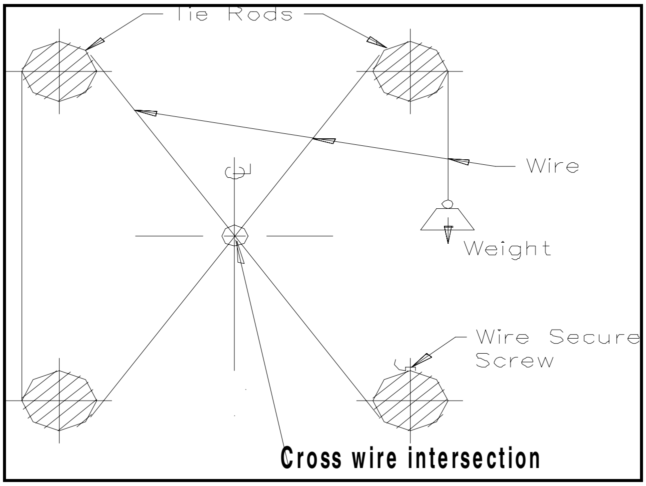


**Figure 2.** Tie rod referenced centering (after Kennedy 1996).

Though these traditional methods and tools have stood the test of time and many are still used today, there are now more efficient techniques using modern technology which not only complement the traditional ones but in many cases replace them. Offset reference points, lines, or scribe marks can be provided by the modern methods during the measurement task to facilitate subsequent adjustment by mechanical methods.

## MODERN TECHNOLOGY

Modern three-dimensional (3D) *Coordinate Measurement Systems* for large-scale dimensional metrology make use of optical measuring systems using different types of instruments. These systems are essentially portable Coordinate Measuring Machines (CMM) allowing rapid deployment to immovable objects for in-situ high precision three-dimensional measurement. Those based on triangulation techniques (horizontal and vertical angles only) use precision electronic industrial theodolites, and high-resolution video cameras; and those based on polar location (horizontal and vertical angles and electronic distances) use precision total stations, tracking laser interferometers, and laser radar scanning. Associated system software allows individual or various instrument combinations for the on-line measurement of the three-dimensional coordinates of selected object points and a wide range of analysis functions to process the object point data. There are also other three-dimensional measuring systems such as mechanical touch probes which use a multi-axes articulated arm with angle encoders, and other hybrid systems based on laser scanning and other rapidly emerging technology. Some of these are generally not practical yet, or have limited range, or are lower accuracy systems, unable to meet tolerance requirements. Precision optical systems typically measure within a 10m cube (33ft cube) object space to better than 0.1mm (0.04inches) and more often to better than 0.025mm (0.001inches).

Digital video cameras are used in close range photogrammetry and videogrammetry systems particularly where large amounts of data points are required to be captured instantaneously and/or when the object is deforming rapidly. Recent *videogrammetry* systems for industry such as V-Stars[7]are now capable of very accurate (better than 10ppm at close range) real time coordination of pre-targeted points and single point targetless measurement with hand held probes using multi-headed camera systems.

*Coherent laser radar scanning* is a new emerging technology with much potential. It too is suitable for capturing large amounts of data points very rapidly (1000points/sec.), and with an accuracy of 2.5ppm.[8].This technology is similar to the laser tracker described below, except the distance is measured using coherent laser radar (absolute distance) instead of a laser interferometer, and the points measured are in vertical sweep scan columns up and down the object instead of single-point contact measurement to a stationary or active retro-reflector.

The choice of the most appropriate measuring sensor(s)/system is dependent on the application and often on access and availability. For extrusion press alignment, which is the subject of this paper, only those instrument systems that are more appropriate will be further described in detail as their principles and techniques represent the majority of modern three-dimensional CMS. These systems are the theodolite triangulation system, the single station polar system, and the tracking laser interferometer. The theodolite system was used in the specific press alignment example discussed here.

## Multiple Theodolite Triangulation Systems

This triangulation system makes use of two or more electronic theodolites intersecting their lines of sight at the point to be measured. The vertical and horizontal angles from each sensor are recorded in the interfaced computer and processed to provide three-dimensional point coordinates (Figure 3).

The theodolites (sensors) are setup at the end-points of bases chosen to provide good intersection geometry. The origin, scale, and orientation of the coordinate system are established by definition of one sensor, observations to a calibrated known length scale bar, and a bundle-adjustment of sufficient measurements to a minimum number of geometrically well-spaced reference points around the object being

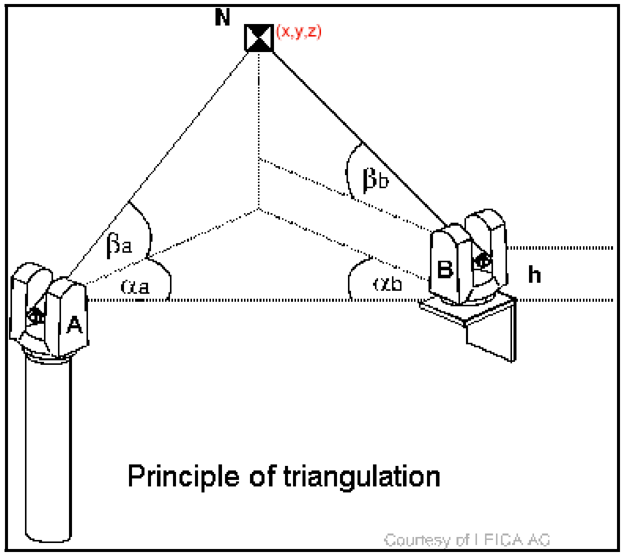

**Figure 3.** Two theodolites intersecting point N.

measured. The theodolite coordinate system can readily be transformed into an object coordinate system via control points with design coordinates. Targets sighted by the sensors can be to a line or point feature on the object; a sphere, plug, magnetic, or tape target; or a laser dot or hidden point rod (for obscured locations). This is a portable, noncontact, self-checking, point-by-point measuring system which can be expanded from a simple dual manual theodolite array to a multiple-sensor automated arrangement using motorized-robotic theodolites with video target acquisition suitable for large point numbers and their repetitive measurement.

Various names for this triangulation type system have included Electronic Coordinate Determination System, Remote Measuring System, Electronic Triangulation System, and Computer Aided Theodolites. Remote measuring systems have been well documented in many publications[9]. A comprehensive overview of remote measuring systems and applications is given in[10]. Coordinate accuracies achieved with this system for objects less than 10m (33ft) are typically 0.03mm (0.001inches).

## Single Station Polar Systems

Polar point determination can be carried out with a single instrument called a precision total station. This is an electronic theodolite with an integrated electromagnetic distance measurement (EDM) device that requires a retro-reflector to return the EDM beam. The two angles (hz&vt) and a distance are transmitted to driving software on-board, or to an interfaced portable computer to provide three-dimensional coordinates of points measured (see Figure 4 for the polar measurement principle). This is

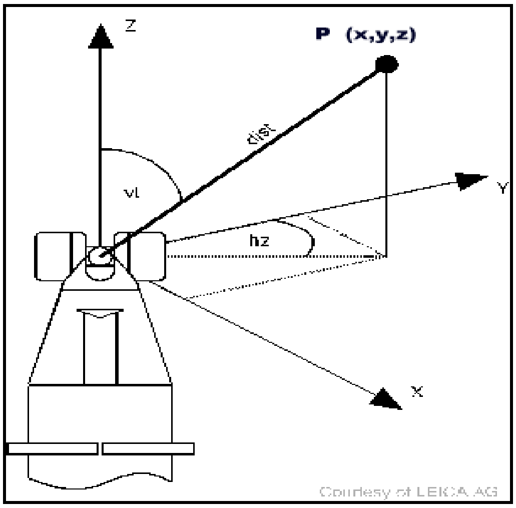

**Figure 4.** Polar coordinate principle.

a single operator, contact measurement sensor that is fast and mobile, is geometry independent, and has its own inherent gravity referenced coordinate system. EDM is the system accuracy limitation at about 0.1mm (0.004inches) to 0.5mm (0.020inches). Targets consist of retro-prisms, and reflective tape, though some, modern total stations now have reflectorless (noncontact) capability. Modern system features are automation and robotics via servo-motor driven theodolite and optics, and video target acquisition for automatic point inspection.

## Tracking Laser Interferometer

The tracking laser interferometer is a polar (Figure 4) measuring system that uses a single beam laser interferometer to measure distance differences to a retro-reflector and a two axes motor-driven tilting mirror with optical encoders for horizontal and vertical angle measurement. A position sensing device (PSD) detects changes in the position of the reflected laser beam caused by shifts in the optical center of the reflector and applies mirror corrections via the motors to track the reflector's center. Correction monitoring occurs at 3000 times per second, enabling the tracking and polar point measurement of a moving reflector at up to 1000 times per second. A factory calibrated and user re-definable distance from mirror to a fixed home point provides the initialization facility for absolute interferometer distance determination. A recent addition to these trackers is a high precision EDM coincident with the laser path to measure absolute distance to the reflector to re-initialize the interferometer whenever its beam is interrupted. Figure 5 shows the components of a tracking laser interferometer. This is an accurate (5 to 10 parts per million of the distance), high integrity, single operator, contact measurement sensor that is mobile, collects vast amounts of three-dimensional data points very rapidly,

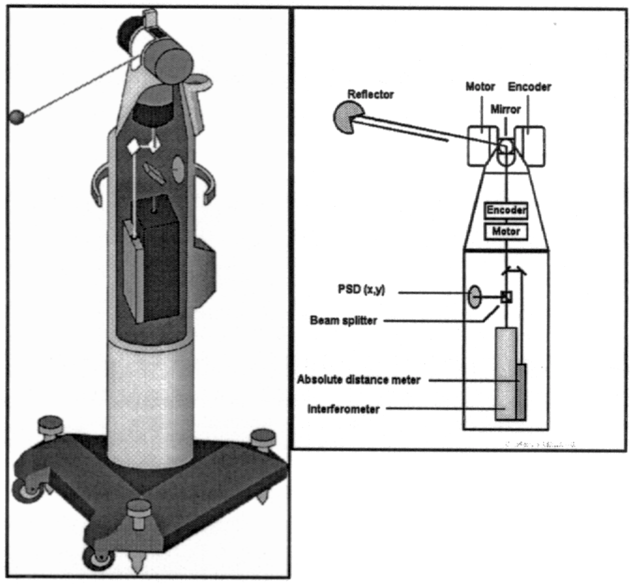

**Figure 5.** Tracking laser interferometer component details.

is geometry independent, has its own inherent coordinate system, and can track and measure a single point on a moving object at high speed (4m/sec [13ft/sec]). Other system features are infra-red remote control, voice recognition, and programmed automation.

The modern CMS software now also allow combined systems of multiple theodolite systems and polar determination systems to be used together for special or larger measurement projects.

## THE APPLICATION OF CMS TO PRESS ALIGNMENT

All these three-dimensional systems essentially sample objects or components to determine their geometric shapes and spatial relationships so that these can be compared to design for establishment or adjustment purposes. For example, the position and orientation of the geometric axis of a tie rod is determined by sampling an appropriate distribution of points along its form to process a best-fit cylinder shape. Further analysis of this axis with those of the other tie rods and the press center line for parallelism will give compliance information. Instead of physically establishing a center line with a piano wire or rod, a virtual center line is mathematically defined which corresponds far more accurately to the true geometric one than the mechanical reproduction. This means that all the points and components required for the complete press inspection can be measured in one session and analyzed in three-dimensions as required in any combination.

Not only can the overall static state of all the press components be measuredat once and in any order, but also all the moving components at their various positions or continuously along their entire path of travel, and under operational conditions of temperature. This may be indispensable to achieve alignment corrected for true thermal growth effects. Moreover, the geometric characterization need only be relative and not necessarily with respect to gravity. For example, if a press base was tilted but still entirely correct geometrically, it would still function properly, though a gravity based relationship allows the application of the traditional alignment tools more easily and in a complementary manner to CMS.

A further diagnostic capability is to combine the CMS with dual axes digital tilt indicators to monitor the movement and distortion of general or specific press components under various operational load and event conditions of ram and container pressure and extrusion. Changes in location and angular attitude of press components between different load and event conditions can be determined or monitored by measuring the altered locations of three points on each relevant component or the relative changes in tilt between a fixed and moving component. The tilt indicators provide a continuous stream of data showing the time-tagged changes in tilt as the press goes through its various operations. The exact time and correlated event when a suspect dynamic component has unacceptable movement/distortion can easily be diagnosed when the stream of data is graphed.

The combined measurements for the static, moving components, and operational monitoring phases were carried out recently in a single day on an older extrusion press (1650 ton) that had alignment problems due to badly worn moving components and a poor damage restoration record at installation. The purpose was to determine the press alignment condition to help determine its long term repair requirements. Figure 6 shows the initial condition of the press and Figures 7 and 8 give optional solutions for adjustment. The adjustment solution (2) applied enabled continued production (with no more sheared bolts!) at minimal cost on a press that would otherwise have been out of production for a long untenable major overhaul. It was not possible to identify or correct the problems using the traditional alignment methods and tools because of their one-dimensional basis and dependence on geometric assumptions/principles that can likely be false.

Another aspect is the manner in which the container (liner) seals onto the die holder, through the tool set (stack) onto the bolster or pressure ring, onto the die holder carrier, and onto the platen pressure

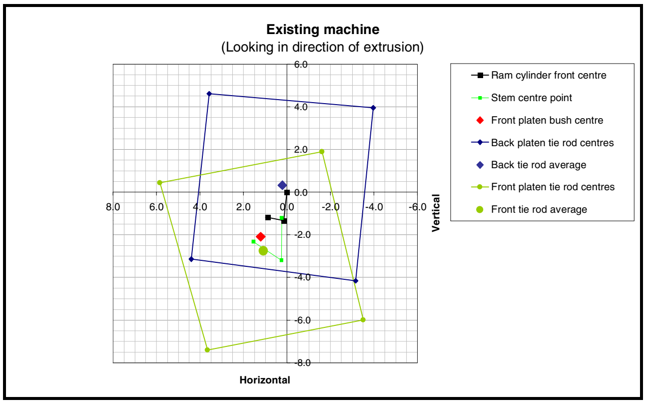


**Figure 6.** Initial misaligned state of press components.

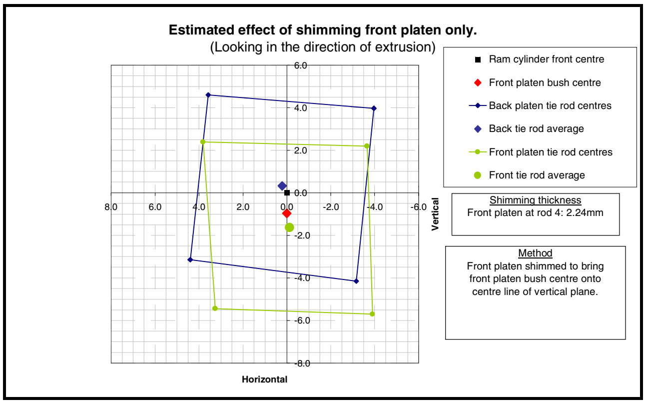


**Figure 7.** Adjustment solution 1: front platen only.

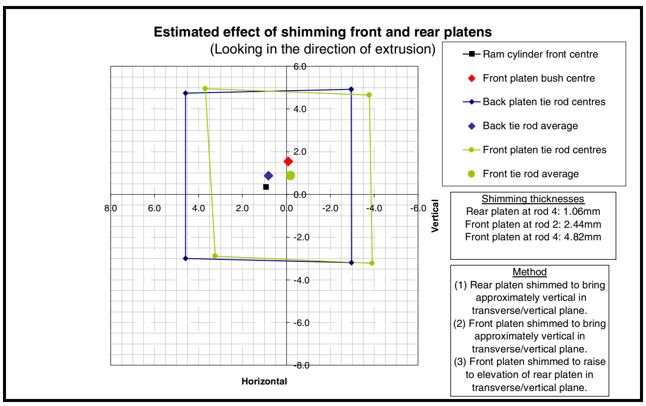


**Figure 8.** Adjustment solution 2: front and back platen.

ring in the egress hole of the end housing (resistance) platen. These surfaces, whether they are flat or taper seals, determine the attitude and consequent press misalignment under operational extrusion pressure; and their measurement is of primary importance. The determination of the above component hole centers with respect to the press center line is considered of secondary importance though parallelism of the assembly center line with that of the press is important. For example, if the face of the platen pressure ring is not parallel to the front platen (determined by measuring the machined tie rod seats), the center of its hole will not provide correct alignment. Equally, after many hours of production, the inside of the container liner and the egress hole in the front platen are hardly going to provide the original machined surfaces, nor are the correct positions of the centering disc or mounting plate for the taut wire or precision tube methods necessarily reproducible or related to the pressure ring attitude. Special plates can readily be designed to aid the measurement with the CMS of the surface attitude and the center of each hole in combination. Figure 9 is a diagram of a flange target plate suitable to fit both the pressure bush and the two ends of the container liner. The smaller diameter stub fits into the hole and has three points of contact (two adjustable to allow for various diameters and to facilitate rotation) to locate the target centrally in several positions as it is rotated. A carbon fiber rod with omnidirectional target is mounted on the outside edge of the flange and is measured in each of the rotated positions. A geometric circle fit to these three-dimensional points provides a center of rotation and axis which respectively define the center of the hole and the perpendicular to the vertical surface of the pressure bush. The critical face of the flange target provides the surface contact of the flange to the vertical surface of the pressure bush (or liner) which, at each rotated position, is measured under pressure so that the attitude is correctly replicated.

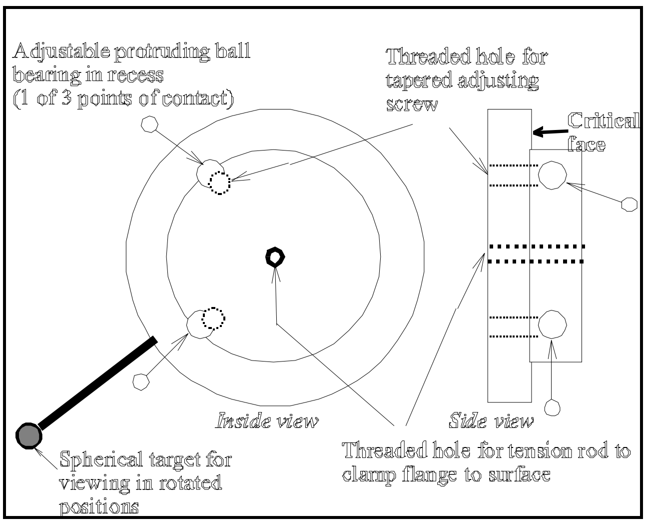

**Figure 9.** Flange target plate.

It is unlikely that aluminum extrusion businesses will have their own three-dimensional coordinate measuring systems though they may have access through a larger firm. Though CMSs have been set up as turnkey systems for effective use by industry at minimum skill level for their specific in-house measurement project requirements, their application to one-off tasks (such as extrusion press alignment) may extend beyond the operators knowledge and training. In any case, these three-dimensional measurements are carried out by specialists or professional services in industrial measurement or large scale metrology. Three-dimensional CMS measurement for extrusion press alignment can provide significant benefits when carried out especially for reactive and preventive maintenance, but also in conjunction with the other condition monitoring and maintenance management techniques.

## CONCLUSIONS

The geometric or dimensional aspects of an extrusion press are fundamental to proper press alignment which is required for minimizing downtime and production waste.

The main three-dimensional geometric relationships can be derived from the original press designer/ manufacturer specifications and together with design tolerances and critical dimensions provide the three-dimensional mathematical inspection model for compliance. Also, an understanding of the press operational principles provides compliance criteria for the diagnostic monitoring and adjustment of the moving components for the various operational load and event conditions. It is difficult to successfully build up the measured three-dimensional geometric relationship from discrete one-dimensional mechanical measurements using traditional press alignment tools. Press alignment, inspection, adjustment and control are now more efficiently achieved using modern three-dimensional CMS technology which not only complements the traditional ones, but in many cases replace them.

Better press alignment and monitoring techniques increase the flexibility, productivity, efficiency, and quality of extrusion.

## ACKNOWLEDGMENTS

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