Setting Up of Robot Welding Line for Car Bodies at BMW Factory in Oxford UK

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Key words: surveying, industry geodesy, industry photogrammetry, control measurement

SUMMARY

Technological facility for welding of car bodies – principle, problems of geodetic measurements during setting up of the main assembling table, and during setting up of the car driveway rolling edges on the service units, in conditions of a fully robotized industrial assembling factory. Problems of industry close-range photogrammetry employment for adjustment of the main planar surfaces of assembling frames and manipulation components.

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1. INTRODUCTION

Industry is one of the specialized fields of enginering geodesy. Generally it covers problems connected with realization of principal planes during assembling of industrial machinery, or measurement of its parameters, respective its adjustment. Applications of industry geodesy are currently working with accuracies from some tenths to hundreths of millimetres. Specific problems are caused by industry environment where the measurements are performed. In an industrial plant the environment is specific by limited space filled by great number of machinery concentrated on relatively close area that are significantly limiting the measuring space, and obstructing the sightlines. Another very significant and disturbing factors are the variable temperature and humidity conditions. Most frequent industry geodesy applications are the measurements for creation of fundamental factory or airport plans, the measurement of geometric parameters during assembling or adjustment of crane rails, rotary and blast furnaces, high chimneys, plate mills, machinery, manufacturing lines, etc.

The BMW Group introduced the MINI in 2001 as a premium brand when it brought the MINI One and MINI Cooper onto the European market. In 2002, the sporty MINI Cooper S joined the family, as did the MINI One D with diesel engine in 2003. The MINI's exclusive birthplace is the Oxford plant in Great Britain. It is completely integrated into the BMW Group's production network.

BMW factories have many sub-contractors all over the world that are participating on the manufacturing technologies. Between them are also some of the Czech machinery works. The KUKA Schweissanlagen GmbH is the traditional German contractor of robotized technologies and one of its sub-contractors is besides f.e. the Zollern Vertriebs GmbH + Co. also the Czech Chropyně Machinery Works, a.s. At end of 2003 we were present in BMW plant in Oxford (as part of an expert team of the Chropyně Machinery Works, a.s.) to ensure the completion and tuning of the fully robotized welding line for car bodies. View of the robotized zone with the welding line is in Fig. 1. From the point of view of the line adjustment it was necessary to ensure geodetically the levelling of the main assembling table and the driveway rolling edges for motion of service cars. Complete preparation of geodetic measurements had been carried out on grounds of the fundamental assembling documentation of the Zollern line which we had obtained together with several photographs of the factory interior environment.

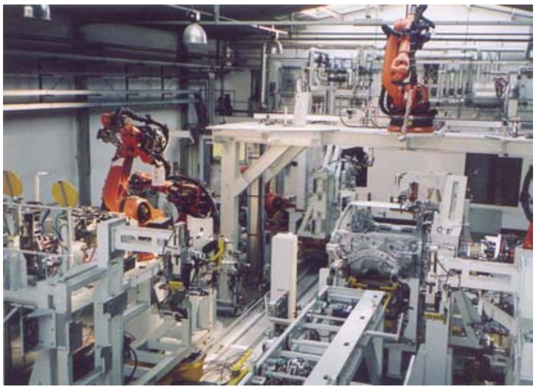

Fig. 1: Robotized welding line

The line for welding of car bodies is one of the components of fully robotized manufacturing zone with great concentration of machinery on a very close area. It is caused by the fact that the line surrounding is maximally exploited by service robots. Another significant complication was the fact that the line had practically been finally assembled and access to the subject of adjustment, i.e. to the line rolling edges, was difficult because of the covering.

2. TECHNOLOGICAL PRINCIPLE OF THE WELDING LINE

Technologically the line for welding of car bodies is composed of the main assembling table 4FX1 with dimensions 2,7 x 5,0 m, where actual welding of car bodies is performed, and of the two (left and right) driveways of 13, 6 m length for four service cars with special

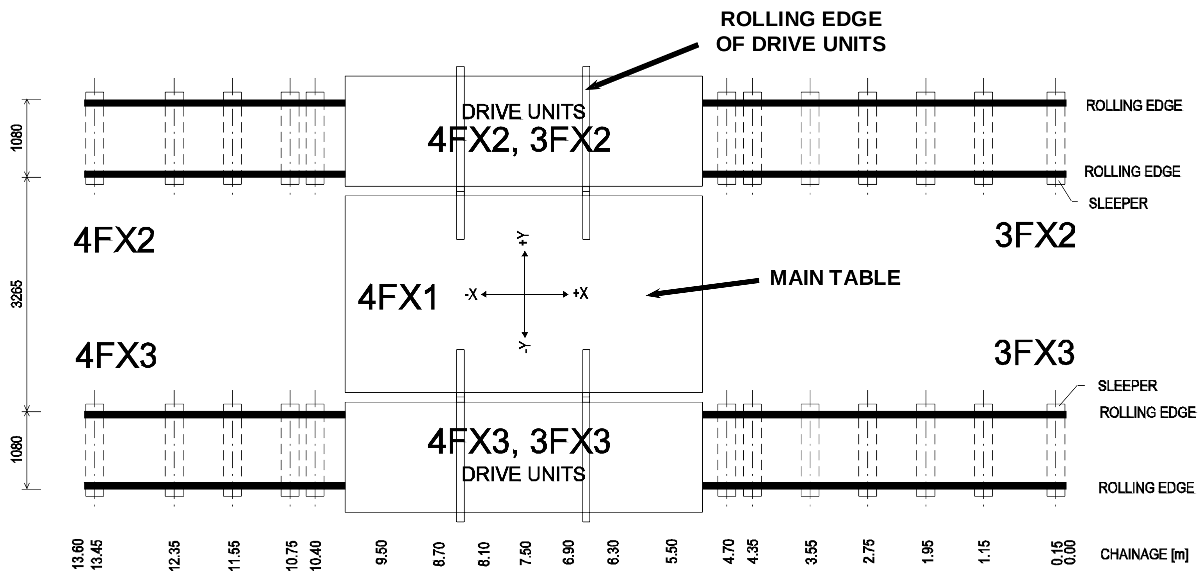

Fig. 2: Scheme of welding line technology

telescopic frames 4FX2, 3FX2, 4FX3, and 3FX3 equipped with systems of grasping tongs. Driveways are formed by two precisely grinded steel rolling edges for driving of service cars. Scheme of the welding line technology is illustrated in Fig. 2.

The functional principle is as follows: skeleton of a car body is placed on the assembling table by automated crane, then the two parallel service cars with frames bring the car body side parts, and after the fitting the welding robots weld the parts to the skeleton. Completed car body is then again grasped by crane and transferred to following assembling units. Setup of the complete line is performed in several steps. Firstly it is necessary to level the main table to horizontal plane, in second step the transversal car rolling strips which serve for slipping of the frames on the adjoining strips of the main assembling table are adjusted. Finally, the strips of the driveways are adjusted to horizontal plane. Further adjustment of mutual geometrical relations between the frames and the main assembling table, including adjustment of the grasping tongs areas, is accomplished with help of close range photogrammetry methods. It covers especially the fixing of mutual perpendicularity and parallelness of principal planes of frames and assembling table. The grasping tongs which are formed by several mechanically joined and grinded areas of dimensions cca 1 x 1 cm serving to grasp the car body construction part must be in exactly defined spatial positions. Resulting accuracy of attachment of the relative positions of single body construction parts including the following welding must be better than 1 mm. Therefore all principal planes within the assembling table have to be set up with accuracies in range from several tenths to several hundredths of millimeter. Relations within the assembling table are determined by close range photogrammetry. It is necessary geodetically to set up especially the horizon of the main assembling table with accuracy better than 0,05 mm, and the service cars driveway edges with accuracy defined by a maximal deviation from horizontal plane ± 0,5 mm in complete driveway course 13,6 m long. Setting up of the horizon is very important because any deviations from the horizontal plane are vertically transferred into space, and it is necessary to match the setting up of adjoining service facilities in upper parts of the line technology. Rolling edges are fixed to the steel driveway core which lies on sleepers with spacing cca 0,6 m - 1,0 m along the line. Details of rolling strips position in a driveway are in Fig. 3. The core is fixed to sleepers by screws which serve for levelling of the driveway. After the adjustment the core is welded to sleepers. Most problematic by complete adjustment of the line are the temperature effects which are transferred into the driveway core by its welding to sleepers, with subsequent driveway deformations. Therefore it is necessary strictly to stand by the specified tested welding procedure. It seemed optimal to adjust the main assembling frame and the driveways at start of the line assembling, Nevertheless, we were asked for collaboration till in phase of completely assembled line. Especially the rolling edges were not accessible because of coverings, and the manipulation space aroud the facility in consequence of great concentration of machinery was very limited.

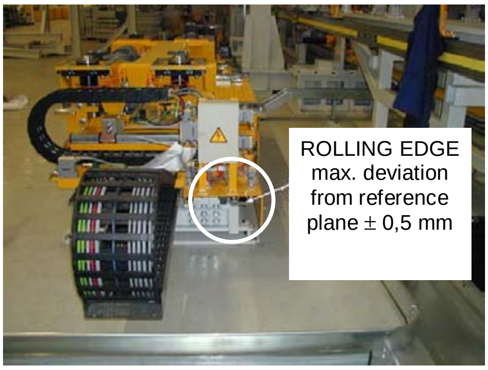

Fig. 3: Position of rolling strips

3. PROBLEMS IN GEODETIC MEASUREMENTS

Precise adjustment of principal parts of the welding line is conditional for successful assembly and following detailed adjustment of adjoining line equipment. As to the geodetic measurements it progressed from the check levelling of the main assembling table, over the adjustment of the transversal rolling edges of service cars in respect to the main table, to the adjustment of the car driveway rolling edges. Results of the main assembling table levelling served as grounds for absolute fixing of the spatial coordinate system. All results had been handed over on the spot to colleagues from Quality Management Department of the KUKA Schweissanlagen GmbH who paralelly ensured the detail adjustment of spatial relations within the assembling table with methods of close range industry photogrammetry.

The characteristic line points were marked on single steel construction elements by precise small drillings to which the special photogrammetric targets were attached. Because the driveway edges were inaccessible, it was necessary to measure the planeness indirectly in time of rolling of the cars along the driveway at precisely adjusted transversal strips, in respect to the main table. Influeneces of the car rolling upon the driveway deformations were not detected. The fact was proved by monitoring the driveway during experimental car roll. The measurements were carried out by precise levelling with optical levelling instrument Zeiss NI005A equipped with optical micrometer. Readings of the micrometer were estimated to 0,5 of the scaling which had value of 0,05 mm. Electronical levelling could not be employed because of sightlines obstructions. Due to complicated local environment (Fig. 4) the readable rod sections were from 2 to 10 cm wide. Frequent use of auxiliary lighting of cross-hairs and micrometer was necessary. Because of the variable sightline distances it was neccessary to introduce the corrections of sightline non-horizontalities to ensure the demanded measurement accuracy. The non-horizontality of a sightline was corrected on grounds of classical instrumental test results. 1,75 m long invar levelling staffs Zeiss had been used, together with special short invar staffs. For unique seting of the staffs to measured places a special bearing bolsters were used. Examples of the special levelling equipment is in Fig. 5.

Fig. 4: Complicated plant conditions

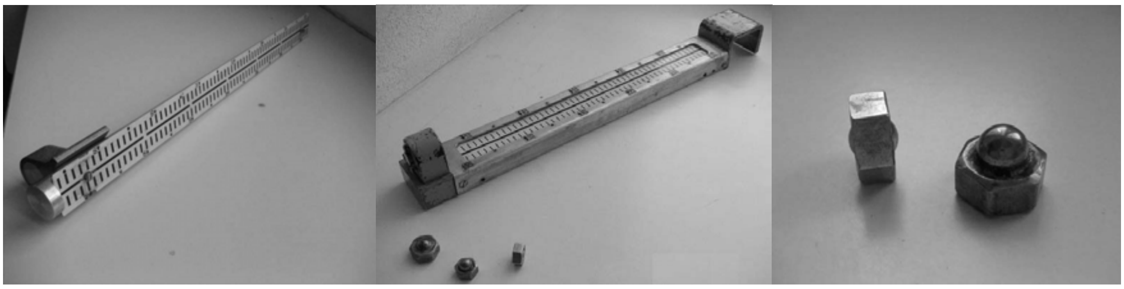

Fig. 5: Special measuring staffs and bolsters

The measurements had to be performed using low tripod setup, and in some cases a special shortened tripod was used. In time of adjustments the atmosphere temperature and temperature of the steel structure had been registered with help of calibrated digital registration thermometer. Accuracy of measured deviations in respect to the main table level, and adjustment accuracy of adjoining transversal car rolling edges was about 0,05 mm. Measurement accuracy in levelling of car driveways was in range 0,05 – 0,1 mm, according to given conditions. Driveways were adjusted above its every sleeper. Due to complicated conditions, elaborateness, and therefore time consuming adjustment course using the sleepers screws, the adjustment final deviations max. ±0,1 mm were accepted exceptionally, with respect to the permitted deviations values. In some places of the driveways less important for functionality the existing deviations up to 0,4 mm had to be accepted because without dismantling of the line parts coverings the adjustment would not be possible. Greater part of permitted deviation had been reserved for the effect of final welding of driveway to sleepers because this phase induces great temperature strains within the steel structure. Even approved welding technology is always bringing significant uncertainties in the final adjustment. In case of getting out of the limits given by permitted deviations it would induce modifications of the welding technological course, with subsequent repeating of the driveway adjustment process. The welding procedure influences are documented in Table 1 by selected deviations criteria in respect to the reference horizontal plane in driveway adjustment, for phases before and after the welding. It is clear that the welding technology practically doubled the RMS values computed from the driveway deviations in respect to the horizontal plane. In some places the welding produced smoothing effects, in other places it induced slight increasing of original deviations. From the final state of deviations it is clear that the demanded tolerances were fulfilled. Measurement results were documented by a protocol elaborated in english and czech versions which had been accepted by the foreign customer without objections. Structure of the protocol was in accordance with the standard ČSN ISO 4463-1.

Table 1:

State of driveway within whole welding line	Max. deviations from horizon in [mm]	RMS in [mm]
Before welding	(-0,23 ; +0,42)	0,07
After welding	(-0,43 ; +0,35)	0,14
Welding influence	(-0,45 ; +0,34)	0,15

4 ADJUSTMENT OF ASSEMBLING FRAMES AND MANIPULATION ELEMENTS

Adjustment of mutual spatial relations between the frames and the main assembling table including the adjustment of spatial positions of the manipulation grasping tongs areas have been carried out by close range photogrammetry methods. This adjustment phase was carried out by Quality Management Department of the KUKA Schweissanlagen GmbH from Augsburg. Adjustment of the spatial relations between principal planes of the assembling table and the frames was done with help of cca 275 photo-images which were postprocessed. Special reflexing markers were attached to the characteristic points of the steel construction, which have been predefined by small bores representing the principal planes. Several tens of additional auxiliary photogrammetric markers in form of square plates with reflexing circular targets were distributed over the main assembling able and the frames. The number and configuration of circles on a marker permitted its individual identification in images with help of special photogrammetric software. These auxiliary markers were exploited for increasing the number of uniquely identified points in images during creation of the spatial model. Location of measuring markers on the frame is shown in Fig. 6 and Fig. 7. Determination of outer orientation elements was ensured by special invar cross carrying measuring markers with exactly known interrelations. For the evaluation of resulting model dimensional accuracy the invar bars with markers were placed upon the main table.

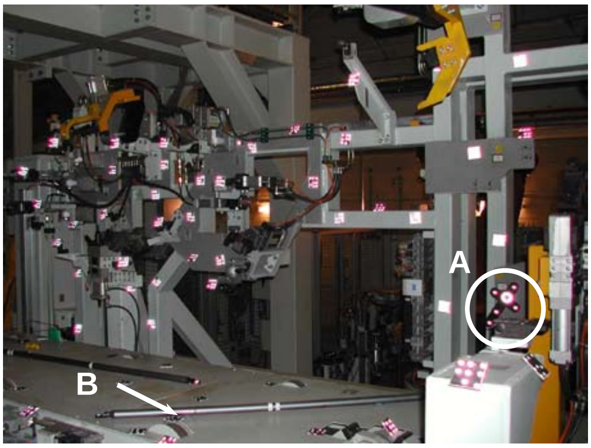

Fig. 6: location of markers on the frame.
Detail A – cross for image orientation
Detail B – invar bar

Photogrammetric imaging had been carried out by special industry digital camera of american made, of the type GSI with Kodak objective, of 6 Mpx resolution. Images were taken from hand, black and white, from a few meters distance. Processing of cca 275 images lasted about 10 minutes. Deviation values for adjustment were obtained by comparison between calculated principal planes points coordinates and the corresponding design coordinates.

Adjustment of manipulation tongs areas has been carried out in real time by two cameras standing on tripods, imaging simultaneously with immediate consequent processing of image

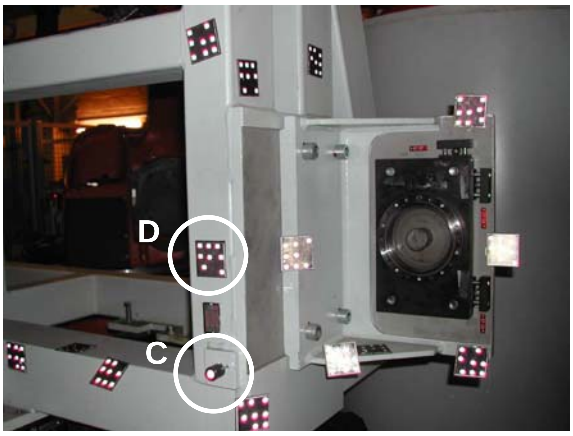

Fig. 7: Detail of CYTEC mounting device for fitting of the frame to main table
Detail C – characteristic frame point
Detail D – auxiliary Photogrammetric marker

Fig. 8: On-line imaging and processing

stereo-pairs at connected computer (Fig. 8). Spatial coordinates were derived from one or more stereo-pairs with high accuracy. Precision of processed relative spatial positions of principal planes had been a few hundredths of millimetre (0,01 – 0,03 mm). Repeating accuracy had been somewhat lower, on the level 0,1 – 0,2 mm for the close range photogrammetry. By real time determination of additional relations concerning the adjustment of manipulation tongs areas the accuracy was a few hundreths of millimetre.

5. CONCLUSION

Fig. 9: MINI Cooper cars manufactured in Oxford plant

In field of industry geodesy there are often high accuracy demands, while the industry environment in given conditions induces needs for use of special mesuring procedures and/or special equipment.. Very precise levelling applied in combination with optical instrument enabling near focusation showed very effective because of the relative simplicity, rapidity, and sufficient accuracy. It was proved that great influence on the geometry has the welding technology, and therefore this factor must not be undercalculated by measuring accuracy preanalysis. Very useful or even unique for adjustment of various detailed spatial relations are the methods of industry close range photogrammetry.

A technological assembling line for automobile industry is always set up for one car type. The welding line adjusted by us is designed to produce MINI Cooper cars in cabriolet modification (Fig. 9). Complete manufacturing line for a single type of a car is composed of several detailed specialized technological lines and it is very expensive.

REFERENCES

Bureš, J., Sláma, J.: 2002, Deformation Measurement of Steel Roof Girders at Factory Building o Prostějov Rail Switch Factory. Proceedings of the 38. Geodetic informations days., ECON Publishing, , pp. 35-40., Brno, ISBN: 80-86433-13-7.(in Czech).

Bureš, J., Klusáček, L.: 2002, Geodetic Measurements During Static Fixing of City Hall Tower in Vyškov na Moravě. Proceedings of the Seminar "Interdisciplinary Applications of Photogrammetry and Engineering Geodesy", STU Bratislava, , pp. 9 – 16, Bratislava, ISBN:80-227-1778-9 (in Czech).

Krumphanzl, V., Michalčák, O.: 1975, Engineering Geodesy II., Kartografie, n.p., Praha (in Czech)

ČSN ISO 4463-1 Measurement methods for building – Setting-out and measurement – Part 1: Planning and organization, measuring procedures, acceptance criteria. (in Czech).

BIOGRAPHICAL NOTES

Ing. Jiří Bureš, graduated in 1994 at Brno University of Technology under the faculty of Civil Engineering. He is working as private surveyor specialist. Since 1997 he has been lecturing at Brno University of Technology, Department of Geodesy. Vicechairman of the Czech Union of Surveyors and Cartographers. His interests are: engineering and industry geodesy, satellite geodesy.

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