Fixture systems and methods for window installation

Tobias Schauerte
Dept. of Mechanical Engineering
Linnaeus university
Växjö, Sweden

Co-authors:
Osama Ziada
Jetro K. Pocorni
Dept. of Mechanical Engineering
Linnaeus university
Växjö, Sweden

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1. Introduction

In the Swedish industry for prefabricated wooden single-family houses and related products like row-houses, about 50 companies with more than ten employees per company are operating (Lindblad *et al.*, 2017). Most of these companies are family-owned, whilst some are part of a larger enterprise or group. Both size and structure of the companies are suggested to have an impact on their ways of working in terms of strategic thinking, intention and degree of investments and willingness of improving operational details (a.o. Schauerte *et al.*, 2016; Schauerte and Lindblad, 2015). One such operational detail is the installation of windows. By that, the authors mean the placement of a window into the wall frame during the prefabrication process. The paper at hand is aiming at describing different fixture systems and methods of window installation. This can be seen as being related to the companies' production flow, that can be increased by using a certain way of installation in combination with a certain fixture system.

2. Different ways of window installation

Depending on the facility layout, the production system and flow as well as the respective companies' deep routed principles and methods of operations, different ways of window installation are applied. The descriptions below are based upon observations during various research activities in different companies in the industry at hand.

2.1. Direct window installation

When installing windows directly, the rest of the wall practically is finished. The wall follows the regular working stages in the production and at the very end of the production process, the wall is raised into an upright position before the windows are installed vertically, see figure 1 and 2. The insulation, sealing and other remaining parts are attached afterwards, see figure 3. The direct window installation is often used by companies that have a production line that only might consist of two or three working stations. The interested reader can find more information on direct window installation in e.g. Pooyan and Yousif (2021).

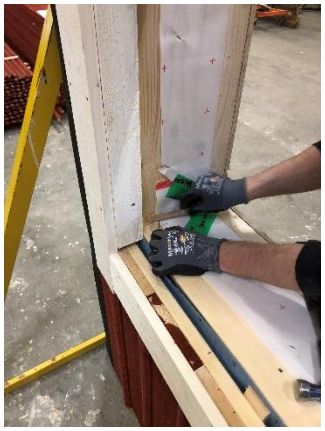

Figure 1: Preparations for direct vertical window installation.

Figure 2: Window about to be installed vertically.

Figure 3: Finalizing vertical window installation.

2.2. Prefabricated window module

Most of the Swedish companies in the industry prefabricate window modules, see figure 4. The modules consist of the window, the adjoining studs, the insulation and sealing around the window. They are prefabricated parallel to the production line and occupy a separate working station and equipment, see figure 5, a separate material flow and at least one operator. Further, the modules need to be transported from the working station to the

framing station, where they, together with the remaining studs, are assembled to build the frame of the wall, see figure 6. The interested reader can find more about prefabricated window modules in e.g. Andersson and Jönsson (2016) or Björk and Andersson (2016).

Figure 4: Prefabricated window module.

Figure 5: Working station for window module.

Figure 6: Assembly of window module into wall frame.

3. Different fixture systems for window installation

3.1. The Adjufix system

The Adjufix system for window installation has been used for decades and is applied by almost all Swedish companies that are engaged in installing windows, independent whether they operate within renovation, new production and kind of houses build. Adjufix consists of two components: an anchor, see figure 7, and a screw, see figure 8. The anchor is either preinstalled in the window frame at the window manufacturer or this needs to be done at the respective house building company. The screw must be fastened from the inside of the window frame towards the adjusting beam in the wall frame, see figure 9. The drilling hole in the window frame for placing the anchor is sealed with a plastic cap. The number of component sets for each window depends on the size of the window.

Figure 7: Adjufix anchor.

Figure 8: Adjufix screw.

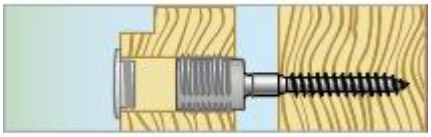

Figure 9: Screw fastened from the left with anchor placed in window frame and drilling hole to the left sealed with plastic cap.

As the screw needs to be fastened from the inside of the window frame, it implies that the window, if possible, must be opened, see figure 10. This in turn means that several working steps need to be performed where the risk to damage the window, especially the glass, increases. Various working equipment are handled by the operators to open the window and to place the screws, like for example portable electric drills or metal hooks and chains for lift cranes.

In case the window cannot be opened, the drilled holes with the anchors are placed at the very outside of the window frame. Yet, as there is only limited space, the operator has to be extremely careful while using the tools to not damage the window, see placement of drilling hole in figure 11. In addition to that, this working task is very unergonomic for the operator, see figure 12.

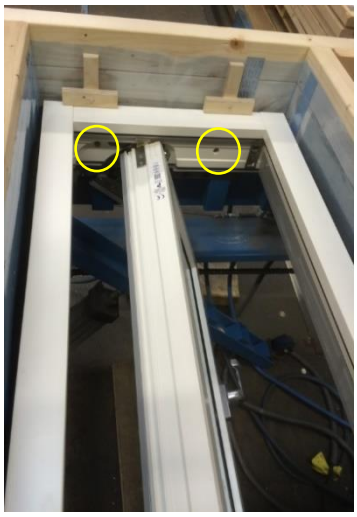

Figure 10: Open window with anchor holes marked yellow.

Figure 11: Closed window with anchor holes marked yellow.

Figure 12: Closed window with operator in unergonomic position when drilling the screw (yellow-marked).

3.2. Click-In fixture system

The Click-In fixture system for window installation has currently been approved and launched on the Swedish market. It consists of two components: a clip in plastic or spring steel, see figure 13, and a screw, see figure 14.

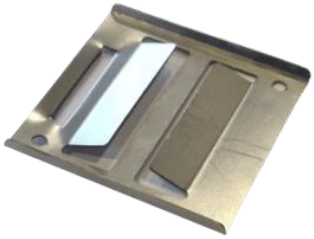

Figure 13: Click-In clip in spring. steel.

Figure 14: Click-In screws.

Figure 15: Attaching a plastic Click-In clip at a window frame.

The clip has holes for attaching the clip at the outside of the window frame, see figures 13 and 15. In the middle of the clip, a snap joint is placed. The screw must be placed at the correct height in the inside of the window opening, see figure 16, so that clip and screw will fit in their positions when the window is in place, see figure 18. When placing the window into the window opening in the wall frame, see figure 17, the snap joint of the clip will glide over the screw head and a "click" sound will be heard (Click-In, 2022).

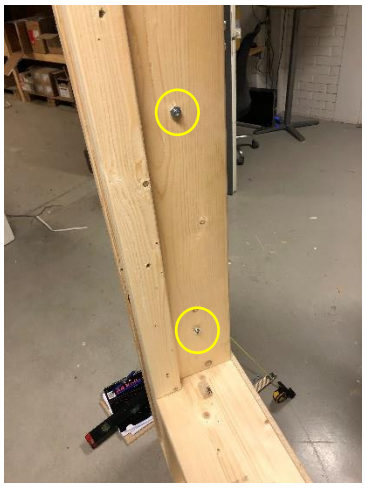

Figure 16: Click-In screws in window opening (marked yellow).

Figure 17: Placing a window into the window opening.

Figure 18: Click-In snap joint glided over the screw head and the fixture system is spring-closed.

4. Comparing Adjufix and Click-In

To compare the two above presented fixture systems, the working steps for each system were studied. For the Adjufix system, both the direct window installation and the prefabricated window module were investigated. For the Click-In system, only the direct window installation was considered, as no case was available to be studied at the time.

For the sake of comparability, different pre-conditions had to be fulfilled. First, a similar window measuring 100x120cm was used in all three cases. Second, as anchor screws belonging to the Adjufix system regularly are pre-installed in the window frame, the clips for the Click-In system were pre-installed prior to the window installation as well, as this is a working step that is to be performed by the window manufacturer before delivery. Additionally, the positions for the Click-In screws were marked in advance. Finally, the installation of each system was done by operators being used to installing the respective system.

The observed working steps for all systems were noted and for each type of installation, five to seven time-measurements were done and the average split-time for the respective system specific time was studied. Finally, the average assembly time for each type of installation was calculated.

4.1. Working steps and assembly time for direct installation with Adjufix

Table 1 shows the working steps 1 – 15 and the seven time-measurements MA1 – MA7 in seconds for a direct window installation with the Adjufix system. Steps 1 – 12 are system specific. Steps 2 – 4 are strongly connected to each other and were hard to distinguish when measuring the assembly time. Thus, the time noted for step 2 includes the times for step 3 and 4. The same was done for steps 5 – 6, 7 – 9 and 10 – 11. The average split-time for the Adjufix specific working steps is 385 seconds.

Working steps 13 – 15 are common and system independent. The total average assembly time for window installation with the Adjufix system is 987 seconds.

Table 1: Working steps 1 – 15 and time measurements MA1 – MA7 in seconds for Adjufix direct installation.

	"Adjufix" fixture system	MA1	MA2	MA3	MA4	MA5	MA6	MA7
1	*placing wooden distance pieces*	23	25	26	26	32	25	23
2	*lifting and attaching window (tasks 2-4)*	39	51	59	58	124	51	44
3	*measuring lateral distance margins*							
4	*locking the window with wedges*							
5	*opening the window (tasks 5-6)*	79	112	93	91	128	112	82
6	*screwing frame screw anchor*							
7	*screwing frame screws (tasks 7-9)*	104	112	195	168	71	82	145
8	*control measuring/adjusting the window*							
9	*removing the wedges*							
10	*closing the window (tasks 10-11)*	17	29	68	119	18	29	40
11	*controlling open/close function*							
12	*sealing holes for frame screws*	40	31	31	24	22	21	26
	split-time working tasks "adjufix" only	302	360	472	486	395	320	360
	average split-time "adjufix" only	385						
13	*caulking with mineral wool strips*	209	219	245	241	192	219	201
14	*caulking with cellular plastic sealing tube*	160	142	143	151	155	142	125
15	*attaching elastic joint sealing*	190	264	245	282	201	264	223
	split-time common working tasks	559	625	633	674	548	625	549
	total assembly time "adjufix"	861	985	1105	1160	943	945	909
	average total assembly time "adjufix"	987						

4.2. Working steps and assembly time for direct installation with Click-In

Table 2 shows the working steps 1 – 5 and the seven measurements MC1 – MC7 in seconds for a direct window installation with the Click-In system. Steps 1 and 2 are system specific, steps 3 – 5 are common and system independent. The average split-time for the Click-In specific working tasks is 385 seconds. The total average assembly time for window installation with the Click-In fixture system is 653 seconds.

Table 2: Working steps 1 – 5 and time measurements MC1 – MC7 in seconds for Click-In direct installation.

	"Click-In" fixture system	MC1	MC2	MC3	MC4	MC5	MC6	MC7
1	*screwing click-in screws according to template*	53	42	40	41	37	35	27
2	*lifting and attaching window*	12	12	12	12	15	12	9
	split-time working tasks "click-in" only	65	54	52	53	52	47	36
	average split-time "click-in" only	51						
3	*caulking with mineral wool strips*	209	219	245	241	192	219	201
4	*caulking with cellular plastic sealing tube*	160	142	143	151	155	142	125
5	*attaching elastic joint sealing*	190	264	245	282	201	264	223
	split-time common working tasks	559	625	633	674	548	625	549
	total assembly time "click-in"	624	679	685	727	600	672	585
	average total assembly time "click-in"	653						

4.3. Working steps and assembly time for prefabricated window module using Adjufix

Table 3 shows the working steps 1 – 16 and the five measurements MP1 – MP5 in seconds for a prefabricated window module using the Adjufix system. Steps 3 and 10 – 12 are system specific, the remaining steps are common working steps and system independent. The average split-time for the Adjufix specific steps is 332 seconds. The average total assembly time for a prefabricated window module is 1814 seconds.

Here the authors ask for caution for a direct comparison with the two chapters above, 4.1 and 4.2, as the window module is prefabricated parallel to the production line. This requires working steps that are not related to the fixture systems itself and that are not part of the window installation process. For example, a different kind of insulation is to be used, which require specific working steps. Furthermore, this is the only way of installing windows, where beams, that act as part of the framed wall, are assembled outside the production line. Additionally, the module needs to be transported to the production line, where it is to be included in the wall frame.

Table 3: Working steps 1 – 16 and time measurements MP1 – MC% in seconds for prefabricated window module using Adjufix.

	"Adjufix" fixture system prefabricated module	MP1	MP2	MP3	MP4	MP5
1	*adjusting window module working table*	88	94	90	45	48
2	*fetching window with vacuum lift*	298	280	312	254	241
3	*preparing for fixing 6 adjufix screws*	130	142	112	105	113
4	*tacking rubber strip inslulation*	62	56	60	58	52
5	*tacking rubber corners*	118	126	138	102	96
6	*placing supporting wood pieces*	20	22	23	20	21
7	*placing window on working table*	40	58	44	41	49
8	*attaching beams around the window*	286	269	305	251	232
9	*pressing and nailing beams to a frame*	334	348	482	304	294
10	*opening window with traverse crane*	60	55	65	58	56
11	*fastening adjufix screws*	129	114	121	115	115
12	*closing window*	32	37	40	29	31
13	*cutting extra wood pieces as filler*	59	55	64	51	49
14	*placing extra wood pieces*	74	89	93	68	66
15	*unfastening module from working table*	55	62	64	49	46
16	*lifting module with crane to palette*	86	98	96	67	62
	split-time working tasks "adjufix" module	351	348	338	307	315
	average split-time "adjufix" module	332				
	split-time common working tasks	1520	1557	1771	1310	1256
	tot. assembly time "adjufix" module	1871	1905	2109	1617	1570
	average tot.ass.time "adjufix" module	1814				

4.4. Comparing and discussing fixture systems and methods for window installation

To start with, the Adjufix and the Click-In systems are compared regarding direct window installation. The Adjufix system requires 12 system-specific working steps, whilst the Click-in system only requires two. For both fixture systems, three common working steps must be added.

Regarding the installation time, the Adjufix specific working steps need 359 seconds to be performed, whilst the Click-In specific steps only take 51 seconds. This means that using the Click-In system can save 308 seconds (ca. 5 minutes) per window. Assuming that an average single-family house has 15 - 20 windows, this would add up to about 77 – 103 minutes per house that the operator potentially can use for other value-creating tasks, e.g. helping out reducing existing bottle-necks to increase the efficiency and greater the throughput of the production system.

This does not only mean that a faster installation can be achieved by using Click-In, it lowers as well the risk for processing errors and material damages. This is especially relevant for the working steps associated to opening the window. For applying the Adjufix system, the windows need to be opened; alternatively, the space for placing the screws is very limited and unergonomic. Related to these steps, a lot of costly customer claims used to fall back on the house manufacturer. If a window gets damages with scratches due to operational failures with tools, the house manufacturer must replace the entire window. This risk ceases to exist when using the Click-In system.

When it comes to the prefabricated window module, the situation looks different. As described in 4.3., a direct comparison can hardly be made. Further, a study on using Click-In for the prefabricated module is not done so far. However, it can be suggested that the Adjufix specific working steps hypothetically could be replaced by Click-In specific steps according to the time measurements made using the direct installation method.

In that case, 332 seconds for the Adjufix steps would be changed to 51 seconds for the Click-In steps and the same time saving per window, 308 seconds, as could be achieved for direct installation, would occur. Yet, as mentioned, this is only hypothetically true. Apart from that, prefabricating a window module takes 1814 seconds, which is much more time compared to the other two ways of installation. Furthermore, the module must be transported to the production line and needs to be assembled to the wall frame, which adds on additional time. Considering the extra space, working table, operator, material flow and so forth, suggests that this seems to be the least efficient way of installing windows.

As many companies nonetheless apply prefabricated modules, and they might have good reason for that which are beyond the scope of the present article, switching from Adjufix to Click-In may reduce their assembly time and thus increase the overall efficiency of their production flow.

Future studies will shed light upon the suitability for the working steps of Adjufix and Click-In to be automated. Due to the functional simplicity of the Click-In system and its components, a great potential for automation by use of a robot system seems to exist. Currently, first studies were started and published (Ziada et al., 2022).

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