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REPORT

AS-0.3200

Ceilbot-project

3.5.2010

Structural platform for Ceilbot

Aim of the structural engineering in this project in spring 2010 was to study the rail transfer system and turntable by structural analysis and 3d modelling. During the project suitable information was collected from literature about rail systems and materials used in railings. As a result, structural railing system was defined, analysed and modelled by Autodesk Revit Structures 2010, which were learned to use during the project. FE-analysis was performed by Autodesk Robot Structural Analysis Professional 2010.

Platform functionalities, visual demands and connection between robot rails and platform were discussed in project team meetings. Last autumn’s home robot team material were used as initial data to define loads and activities. Based on collected information calculations for main profile and anchor were generated.

Platform functionalities

Robot platform should be so called open system, where different commercial railing systems and ceiling structures can be used. Also material of the platform grid should be variable, if needed. Platform shouldn’t cause unnecessary dead load to the structures.

Objective for visual look

All structures should be behind ceiling structures from visual point of view. Only building technique and thin track for robot rails should be visible.

Commercial railing systems

During literature search there was found, that there are wide range of commercial railing systems. Some of these systems are referred in reference. There are several systems suitable for home robot rails.

Loads

There were found robots with own weight of 75kg in initial data. The project team discussed what should be the right dynamic factor for calculations. One possible load case is human hanging from the trunk. That case was considered as accidental load which need to be calculated but not in service limit state. Dynamic factor needs to be researched more specifically when robot planning is moving ahead. Robot live load was assumed for 50kg. Moments of the trunk were roughly estimated, but more specific information is needed during trunk planning.

Ceiling material were assumed to weight 20kg/m2. As a comparison 13mm gypsum board weights about 9kg/m2.

Profile types and optimization

Basic profile types are I-profile, tubular profile and C-profile. C-profile was chosen for robot platform, mainly because of easy installation and economic reasons. Other profiles are also possible to use, depending on the loading and environment of the usage.

Bottom of the C-profile gives open surface to install robot rails, other installations and ceiling structures. Benefits of the open C-profile is possibility to manufacture by extruding aluminium or cold forming steel.

Profile size was estimated as a simple supported beam, when the result is on safe side. Multiple spans reduce deflection. Deflection limit was set to L/1000, which is very typical for bridge cranes.

Materials

Steel weights ~7850kg/m3, has E-modulus of ~210MPa and typical yield stress 235...3555MPa. Steel profiles can be manufactured by casting, hot rolling, cold forming and welding.

Aluminium weights ~2700kg/m3, has E-modulus of ~70MPa and typical yield stress ~110...150MPa. Pure aluminium has poor yield stress of ~10MPa and it needs alloying for improving its quality. There are special alloys that have strength over 600MPa and have good strength and elasticity in very low temperature. Aluminium profiles can be manufactured by casting, extrusion, cold forming and welding.

Steel and aluminium are both recyclable materials. Parameters and qualities can be adjusted in both materials by mixing and casting various alloys and post-processing.

Aluminium has maximum allowable temperature for tension between 200...250°C, which is considerably lower than steel. Because of that, aluminium’s conductance of electricity and heat is about 60% of copper electrolyte.

System of measurements

Platform system was modelled by modular system, where 1M=100mm, and it multiplies 2M...nM. System is adjustable also to spaces where measurement is not modular. Vertical measurement system is the same and also adjustable.

Basic components

Platform system were analysed and modelled consisting several components:

1) Fastener
   - mechanical or chemical anchor in concrete, screw or bolt in steel and timber
2) Damper
   - EPDM rubber or similar
   - In robot rails own damping system
3) Profile
   - Extruded aluminium profile
4) Ceiling hangers
   - free for all materials and systems
5) Ceiling

Conclusions

Aluminium and steel are most applicable for platform profile. The EI/m-ratio is most efficient in these materials, compared to other general materials. Aluminium is also possible to form in complex and curved forms by extruding method. Extrusion is widely used method and there is knowledge and equipment available. Cutting and drilling of aluminium is easy, but welding should be done off site.

Platform grid should be dense, because loads from robot and ceiling should be distributed to the structural ceiling as uniform as possible. This will distribute loads to several anchor points and reduce stresses in ceiling. Dense grid also enables the use of small profile sizes and therefore keeps own weight as small as possible. Minor own weight and dense grid gives better results for deflection analysis and makes tight deflection limits (L/1000) possible. Negative side of dense grid are amount of fasteners and therefore amount of dampers.

Platform is also possible to use as joint suspension system, where robot platform is also platform for other installations, e.g. HVAC, automation and electricity systems.

Recommendations for further studies

Further structural research and development should be performed for minimizing platform own weight, it should be under 20kg/m2. Use of cold formed steel profiles should also be studied, it might be one way to reduce weight.

It is also import to study height of the platform and its optimization.

Amount of fastening points should be minimized, e.g. crossing section design and shaping of the joint.

One key issue is damping and especially structural born sound insulation.

Platform system usability in walking robot should be research.

References

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